Vol. 14 NOVEMBER, 1943 No. 5

# SURGERY

*A Monthly Journal Devoted to the Art and Science of Surgery*

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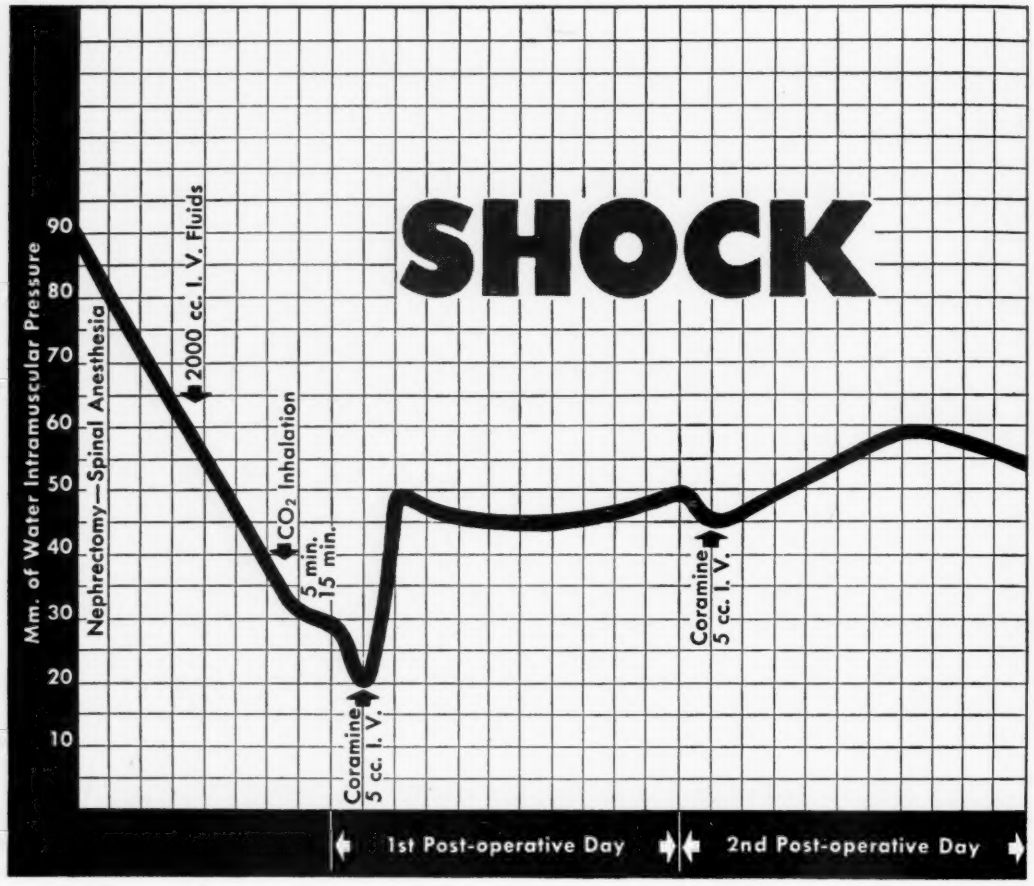


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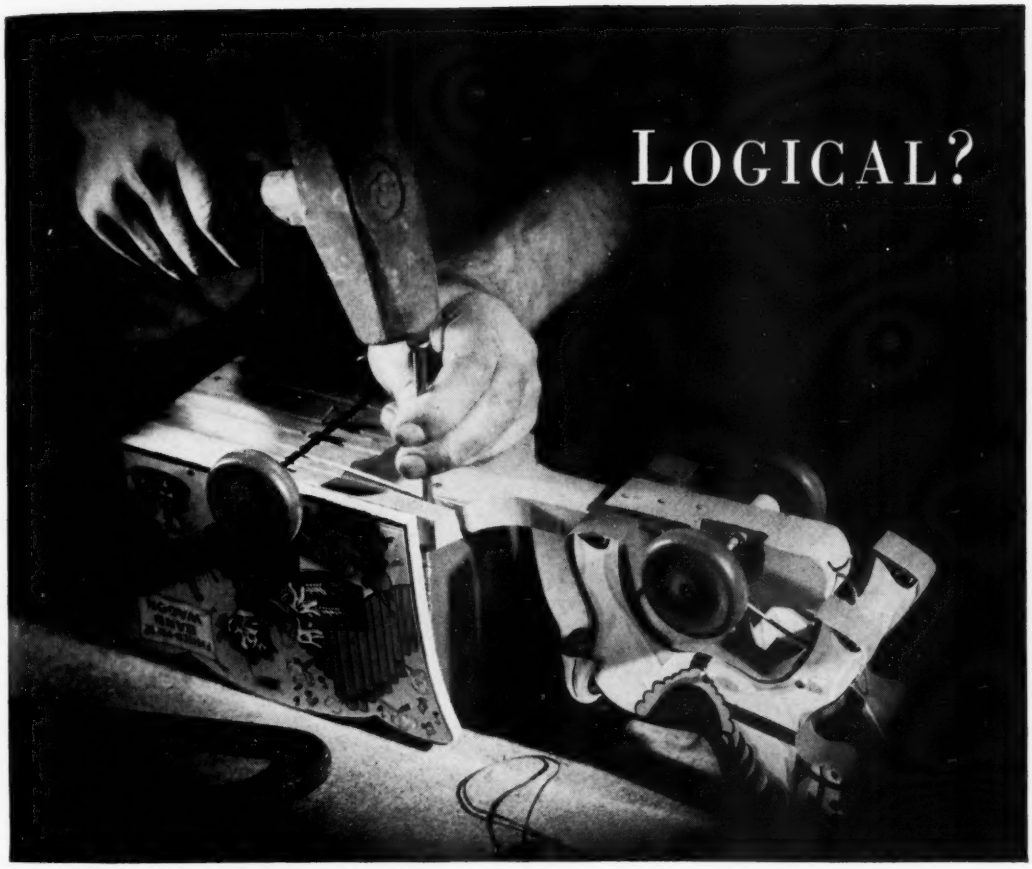


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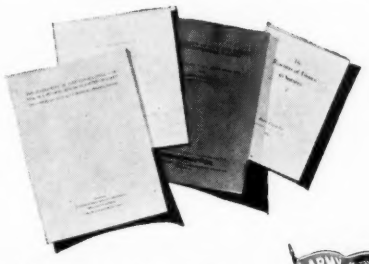

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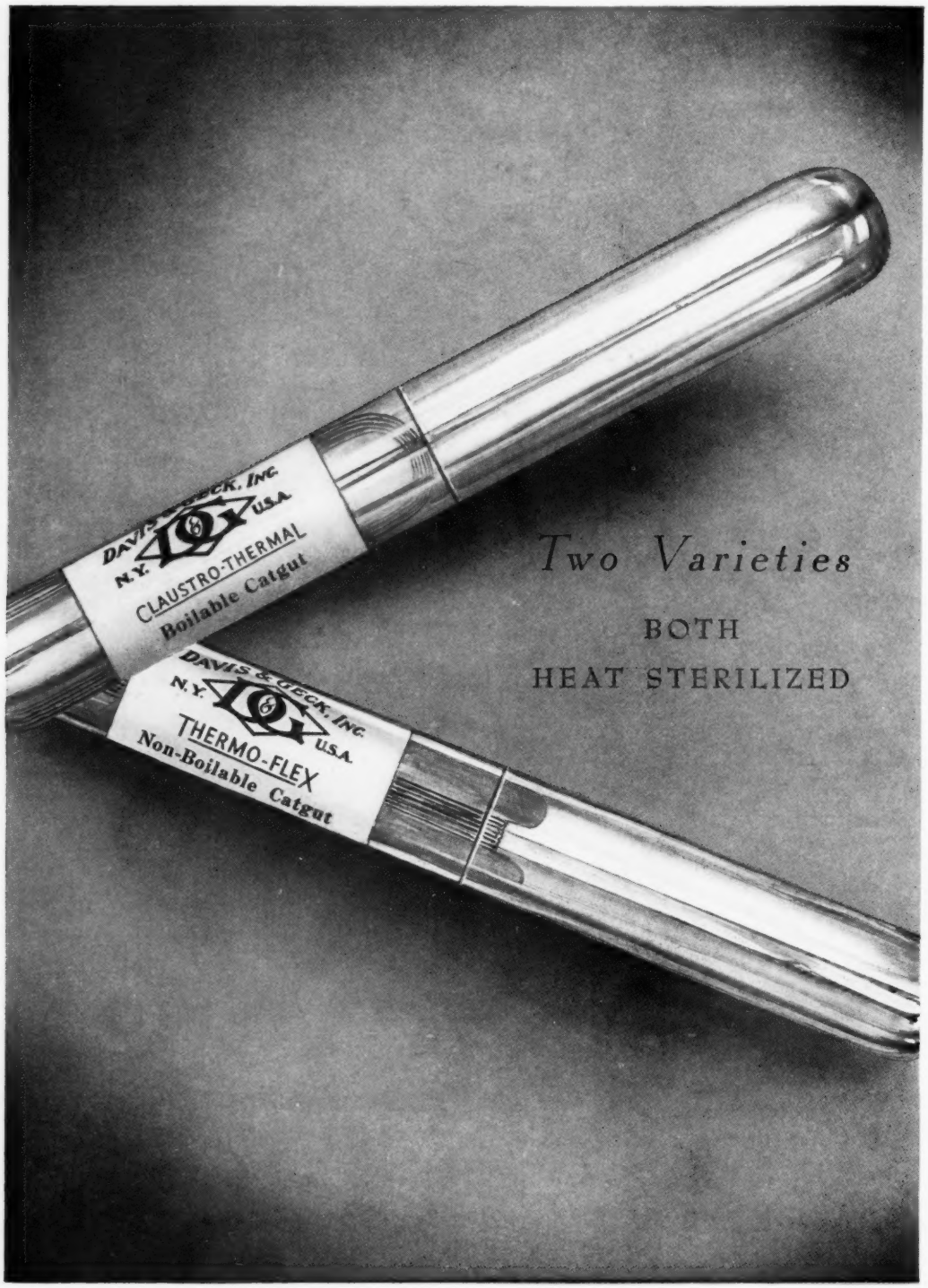


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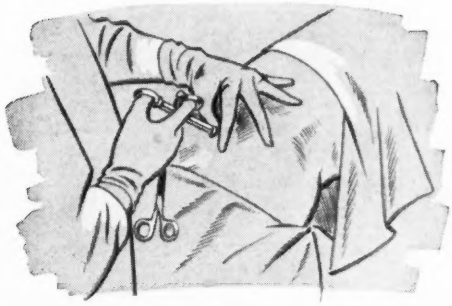

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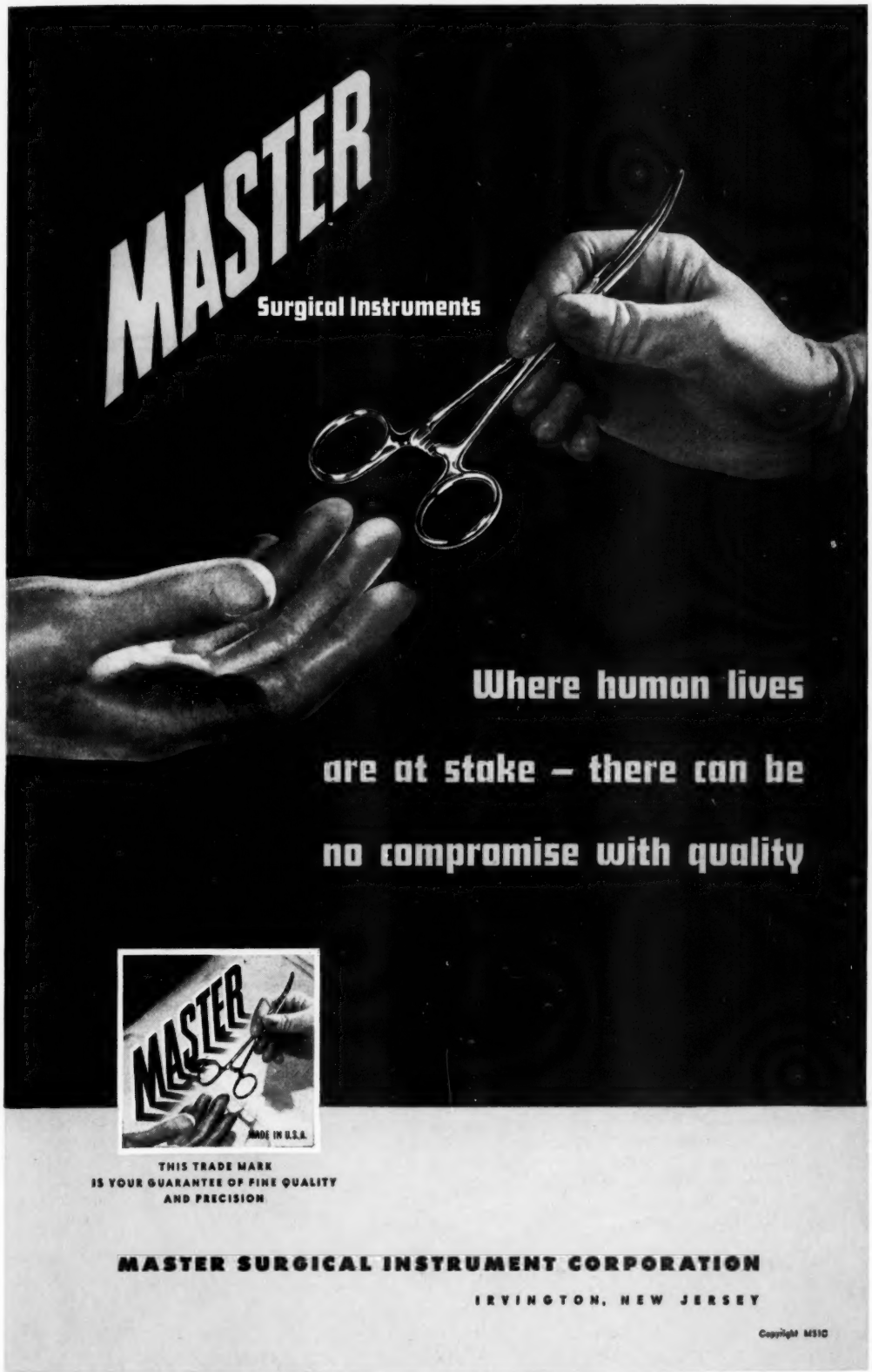


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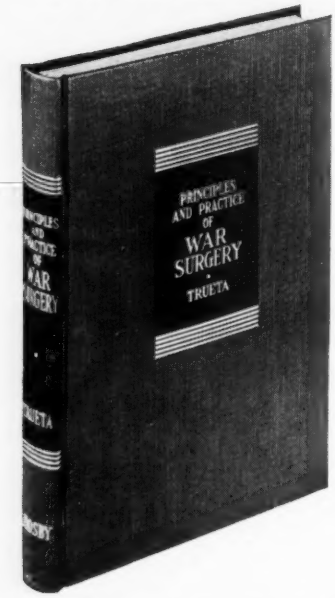


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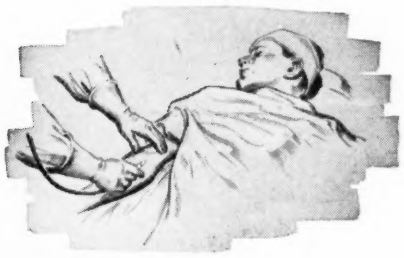

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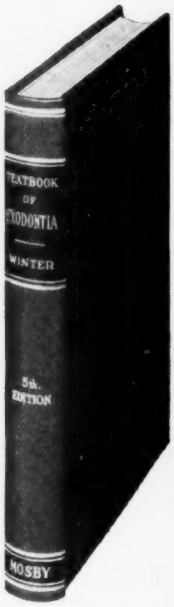


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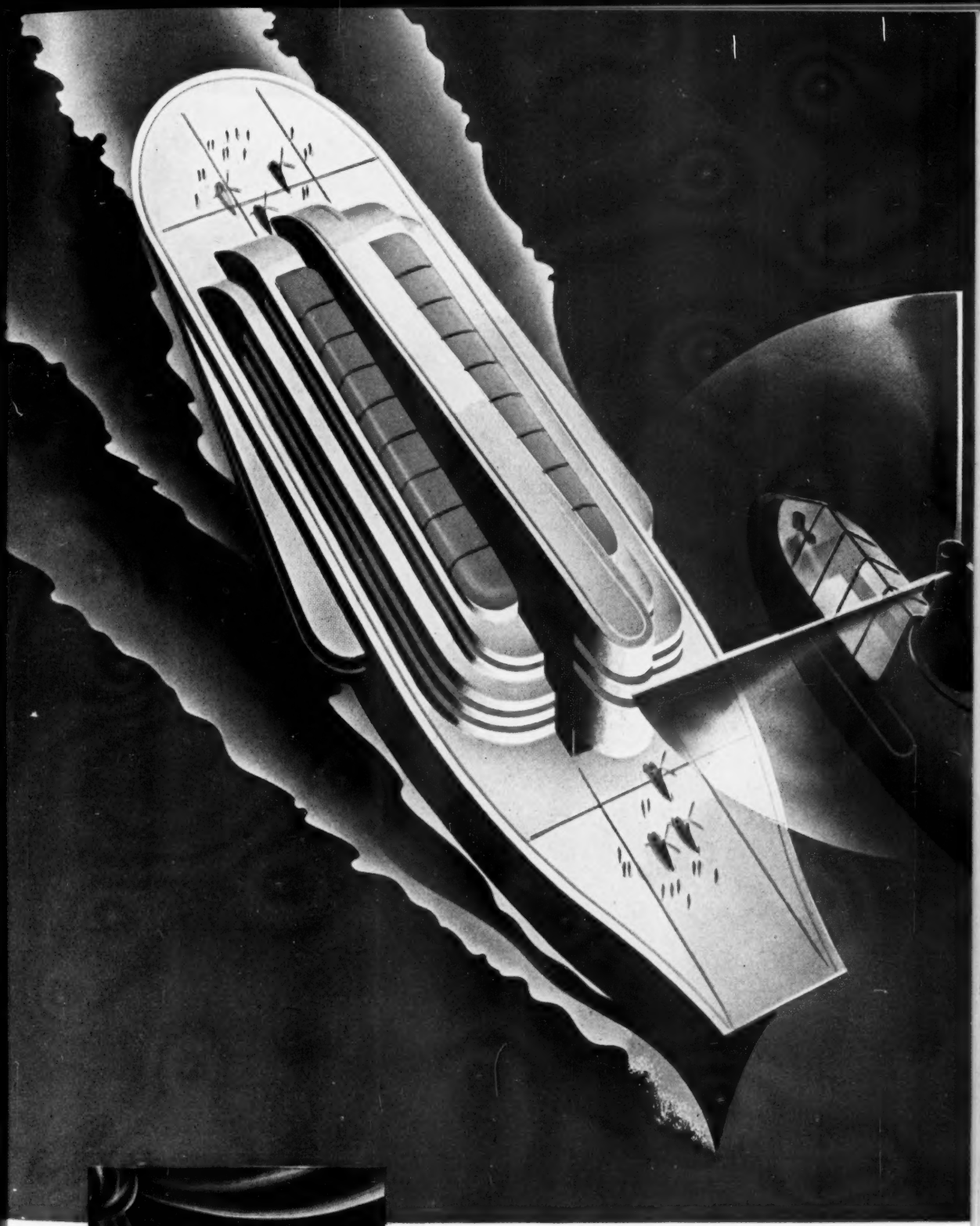


# ETHICON SUTURE "FUTURES"

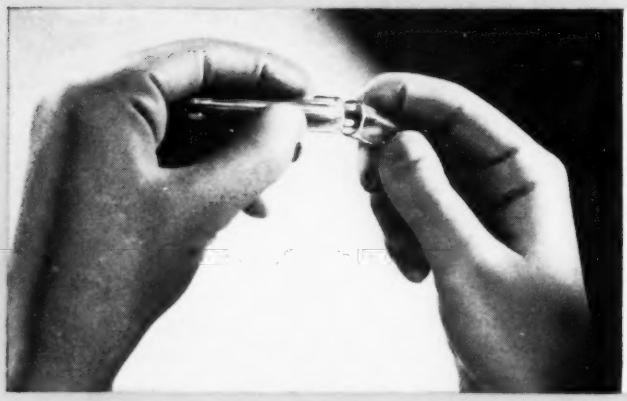
NO. V

**HOSPITAL AIRCRAFT CARRIER...** Visualized for active aid in post-war medical rehabilitation is this super-hospital ship. Fully equipped with wards, solaria, operating rooms, the vessel can be quickly sent wherever needed. Planes bring patients from inland. Landing deck tunnels through solarium to stern. For latest developments in suture making see following pages. ➔

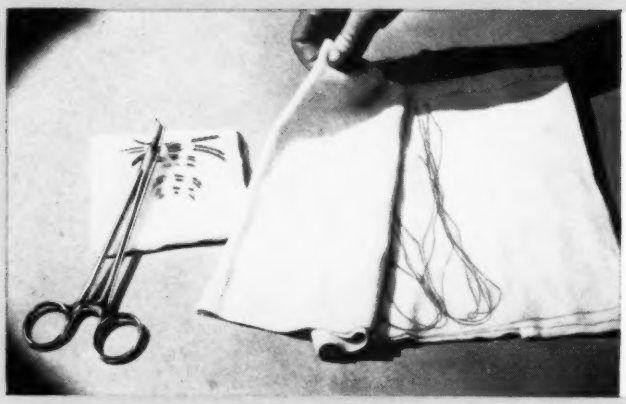
# TECHNIC of handling sutures in the operating room

**Important to the surgeon is the care with which sutures are handled and prepared for his use. A few simple steps assure that the Ethicon Suture you rely upon when you bury it in your patient's tissues will have the same dependable qualities of the tested suture sealed within the tube.**

**Illustrated on these pages are practical methods which are generally followed to protect the integrity of the strand.**

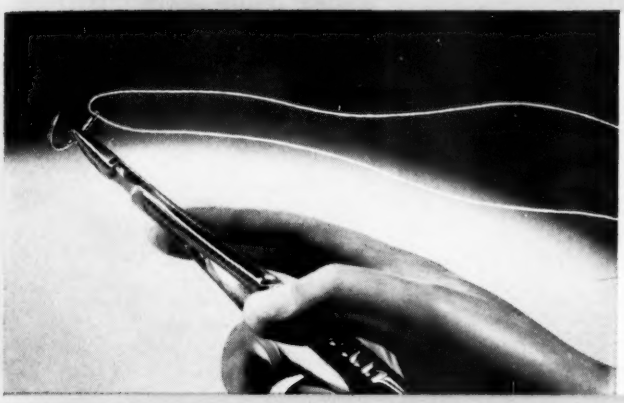


● Before tube is opened, reel is shaken into one end. This position keeps suture away from broken glass edges, which might easily scrape and damage the suture.



● Sterile sponge and moist towel technic for protection and convenience, while sutures await threading to various needles required by surgeon as the operation progresses.

● Some surgeons and nurses prefer to thread a curved needle from the inside, in the belief that it prevents suture from slipping. When a suture slips, it may be damaged and may have to be rethreaded, causing loss of time and material.



● Orthodox position of needle in needle holder, permitting full bite into tissue. Grasping needle away from eye prevents possibility of crushing suture and eye of needle.

● In holding a suture, care is taken not to apply hemostat or crushing forceps to any portion of suture to be left in situ, eliminating possibility of leaving damaged suture in tissue.

## *To complement your technic ...specify Ethicon Surgical Gut*

Ethicon Surgical Gut Sutures have superior gauge-uniformity, which gives greater uniformity of strength. The exclusive Johnson & Johnson Tru-Gauging process gives Ethicon Sutures 6 times greater uniformity of size than required by U.S.P.

For all that is best in a suture, to serve your skill as a surgeon . . . specify Ethicon.

**ETHICON**

LOCK KNOT

**SUTURES**

Johnson & Johnson

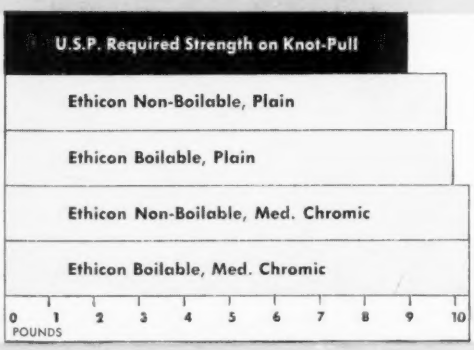
# ETHICON

LOCK KNOT

SUTURES

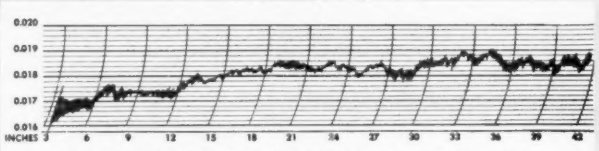
## UNIFORMITY OF TENSILE STRENGTH

This chart gives an example of how uniformly Ethicon Surgical Gut exceeds U.S.P. requirements. The chart shows averages on knot-pull breaks on samples from lots, numbering hundreds of thousands of individual tubes, released by the J & J Laboratories.


U.S.P. Required Strength on Knot-Pull
Ethicon Non-Boilable, Plain
Ethicon Boilable, Plain
Ethicon Non-Boilable, Med. Chromic
Ethicon Boilable, Med. Chromic
0 1 2 3 4 5 6 7 8 9 10
POUNDS

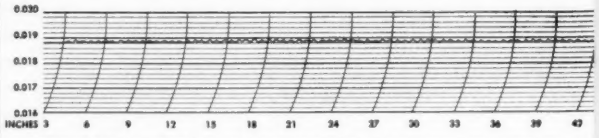
## UNIFORMITY OF GAUGE

Johnson & Johnson's exclusive Tru-Gauging Process gives greater uniformity of tensile strength. The graphs at right, made on a photoelectric microgauge, show that a hand-polished suture meeting U.S.P. requirements may vary in diameter more than 6 times as much as an Ethicon Suture.




HAND-POLISHED SURGICAL GUT SUTURE
*Meeting U.S.P. Requirements*

Size 1, charted by the photoelectric microgauge, shows diameter irregularities along entire length of strand.




ETHICON TRU-GAUGED SURGICAL GUT SUTURE

Size 1, charted in same manner by the microgauge, shows gauge uniformity resulting from Tru-Gauging Process. This gauge-uniformity gives greater uniformity of strength by eliminating "low spots" that cause weakness.

## TRU-CHROMICIZING

Tru-Chromicizing (exclusive with Ethicon Sutures) resists premature absorption. Many sutures are chromicized merely on the surface. Note the even distribution of chrome throughout the Ethicon Suture cross section.

CHROME-DIPPED SUTURE

ETHICON TRU-CHROME SUTURE

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IN the last two decades Trichomonas Vaginalis has been recognized as the most prevalent of the gynecological infections. Incidence has been averaged at between 25 and 30 per cent.

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**VIOFORM INSERTS** may be given to patients for home use, necessitating fewer office calls in these war-rushed times. In mild cases one course of ten days is recommended. More severe infections usually respond to two or three courses. Write for literature.

[1] Am. Jl. Surg., 33:523, 1936
*Trade Mark Reg. U. S. Pat. Off.

CIBA *Pharmaceutical Products, Inc.*
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# SURGERY

VOL. 14 NOVEMBER, 1943 NO. 5

## Original Communications

### THE SURGICAL SERVICE OF A STATION HOSPITAL IN THE MIDDLE EAST

FRANKLIN E. WALTON, M.D.,* NEW YORK, N. Y.

THE doctor in civilian practice along with the medical officer in one of the armed forces in a home station unquestionably asks himself and others, "What are those medical officers overseas actually doing of a *professional* nature at this time?' "This time" is the spring of 1943 and the object of this communication is to acquaint this anxious and puzzled medical public with the scope and activities of the surgical service of a numbered station hospital in the Middle East. For obvious military reasons this answer must be clothed in ambiguity. The exact location of this particular medical installation, its capacity, and the number of patients cannot be disclosed. Because of the plethora of rumors and innuendos in circulation today a statement of facts should be welcomed by the medical public at large. If a careful perusal of the following statements will result in a clearer conception of the professional experiences of this installation, the thought provoking summation must bring some satisfaction to those in service at this time and perhaps stimulate the activities and imaginations of others.

The proportion of surgical cases to total admissions is shown in Fig. 1. The relative constancy of this proportion, some 43 per cent, only reflects the general character of the medical and surgical demands of this particular area of command.

Fig. 2 illustrates the proportion of elective surgical cases in comparison with the acute surgical emergencies. These elective procedures ran the gamut of possibilities from prostatectomies and rhinoplasties through various plastic procedures that had not been carried out in the United States. Though the emergency procedures obviously fluctu-

*Major, Medical Corps, U. S. Army.
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ated from time to time, these elective possibilities were always with us and were relatively constant; they depended upon the abilities of the respective surgical specialists.

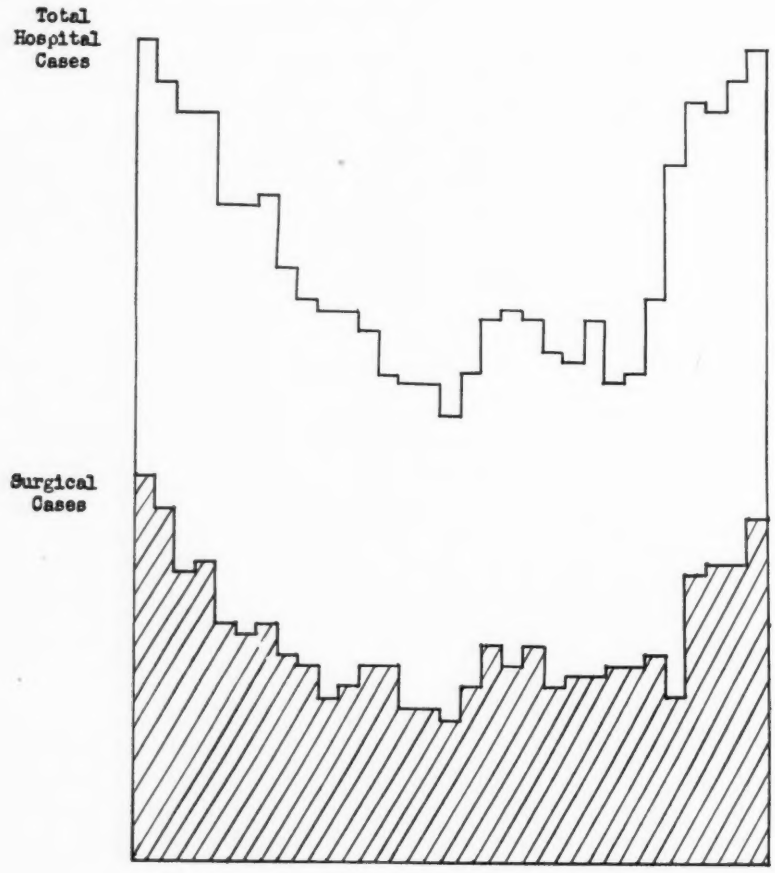


Fig. 1.—The proportion of surgical cases to total admissions.

The type of anesthesia employed is shown in Fig. 3. It will be noted that in roughly one-sixth of the operative procedures no anesthetic was used. This relatively large group included patients (many of whom had received basal drugs) with fractures without displacement, for example, and others in which, because of sound surgical reasons, anesthesia was contraindicated at the time. The group that was administered sodium pentothal is not included in the graph, although this drug was used with excellent results in those requiring surgical dressings of a painful nature, and in brief surgical procedures not requiring muscular relaxation. Brachial block was employed with much satisfaction in many surgical procedures, particularly in fractures of the upper extremities. Spinal anesthetics were administered by the surgeon in charge of the case and the remaining functions of the anesthetist assumed by a medical officer or a trained corps man

under adequate supervision. The inhalation anesthetics, ether, chloroform, and nitrous oxide oxygen, were administered by a medical officer or by a corps man or nurse under the supervision of a medical officer. All were surprisingly satisfactory and there were no alarming complications from a single anesthesia.

The personnel of the operating team consisted of two medical officers, one scrub nurse, one corps man scrubbed to assist the nurse, an anesthetist, one circulating nurse, and two corps men to assist this last-named nurse. Additional medical officers were added to the operating team when the need was apparent. On one particular occasion, seven such teams were functioning simultaneously.

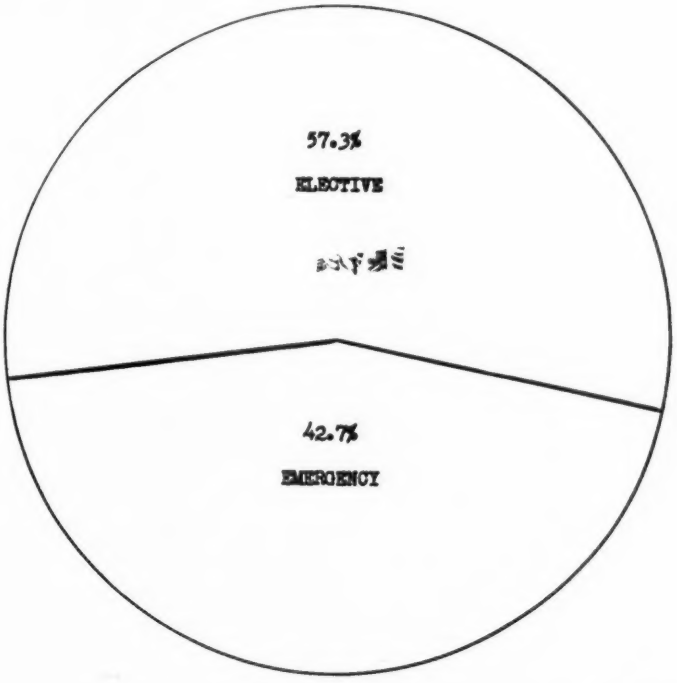


Fig. 2.—The proportion of elective surgical cases in comparison with the acute surgical emergencies.

The breakdown of surgical cases into types of operative surgical procedures shown in Fig. 4 is self-explanatory. The obstetrical group included normal deliveries and the gynecologic procedures were not abdominal but all vaginal in type.

An extensive educational program was instituted and carried out in conjunction with the normal activities of this relatively busy surgical service. The unit fortunately contained officers who, in civilian life, had carried out important roles in the educational activities of university hospitals and medical schools and this fact added considerable emphasis to such a program. It included refresher courses in subjects such as anesthesia, with didactic lectures and clinical demonstrations.

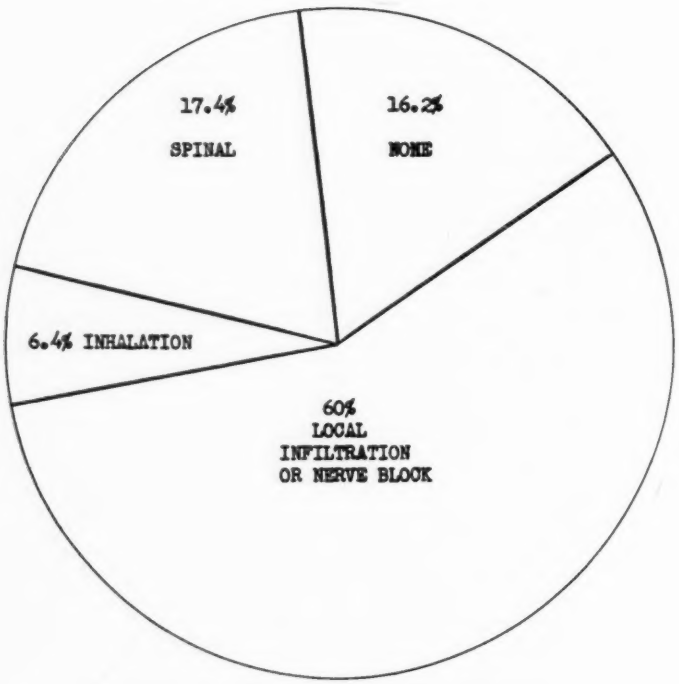


Fig. 3.—The type of anesthesia employed.

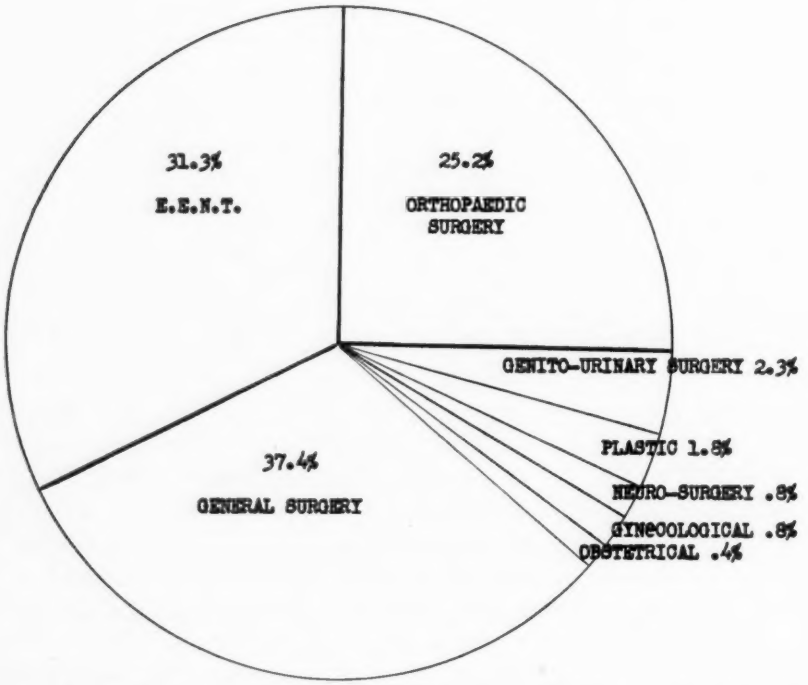


Fig. 4.—The breakdown of surgical cases into types of operative surgical procedures.

These were attended by corps men, nurses, and medical officers alike and were extremely well received. The head nurse on each of the surgical wards, with the aid of her assistant, drilled the corps men assigned to her respective ward in those nursing procedures expected of the corps men. These included assistance with surgical dressings, and handling of patients, as well as mechanical procedures such as the serving of trays, etc. The principal nurse in the operating room held daily drills in which the corps men were taught the theory and then allowed to carry out "scrub up" procedures. They were eventually allowed to scrub for operations and thus actively participated under the direction of a competent nurse. In like fashion these enlisted men received training in the duties of the circulating nurse—the position of the patient, the taking of blood pressures—and in assisting the anesthetist.

Weekly surgical pathologic conferences with presentation of cases, patients, the surgical specimens, x-rays, etc., were held for the entire professional staff and attended by the nurses who were available at that period of the day. Subjects under discussion included, in addition, such "peace time" subjects as surgical lesions of the thyroid gland, internal derangements of the knee joint, a symposium on acute appendicitis, fractures of the humerus, tumors of the anterior triangle of the neck, pneumococcal mastoiditis, infections of the hand with particular emphasis upon human bites, fractures of the pelvis with rupture of the bladder, pathologic fractures of the long bones, and acute mesenteric thrombosis.

The role of the department of radiology in the function of the surgical service cannot be underestimated. The coordination between the two departments was manifest at all times; radiology was purposely located in a section immediately adjacent to the operating room in which all orthopedic cases were cared for. Their service not only offered the routine x-ray and fluoroscopic procedures, but gastrointestinal series, cholecystographic studies, encephelograms, pyelograms, myelograms, etc.

In a similar fashion, the laboratory service carried out such tests as sulfanilamide determinations, $CO_2$ and $O_2$ tensions, total and fractional serum protein determinations, Friedmann tests, blood chlorides, Ca and P determinations, anaerobic cultures and provided twenty-four-hour rush hematoxylin-eosin paraffin sections.

Because this installation was located in the zone of combat, although upon its fringe, the "52 Series" or short type of case record was used throughout. However, adequate charts were maintained on each patient for the benefit of the ward officers and the nurses, and later discarded. The paper work in this fashion was minimized by army regulations, supplemented as described above, and proved adequate. Technical and surgical equipment was most complete and reflected thoughtful and careful planning through the services of supply.

The ultimate goal in any medical installation is the result in terms of properly handled patients. The answer may be obtained from the pertinent words of a lieutenant-general of the line who recently inspected this hospital. After visiting some of the wards he turned and said, "I know you have an excellent medical installation here. Its character is reflected in the expression on the face of every patient I see."

In conclusion, let those physicians at home, either in civilian practice or in the service, rest assured that in this numbered station hospital, the medical officers with the excellent assistance of the departments of radiology, the laboratory and physiotherapy, are practicing their respective specialties with equipment in most instances far superior to that available in the United States at the time of this communication. The satisfactory results that are being obtained reflect the excellent medical training these medical officers have had and bespeak the cooperation that holds among all the services of supply.

# TRAUMATIC SURGERY

## A Review of Some Bone and Joint Injuries in Wartime

A. G. Ord, F.R.C.S. (Edin.), Ralph Shackman, M.B., F.R.C.S.* (Eng.), and H. L. M. Roualle, M.D., F.R.C.S. (Eng.), London, Eng.

*(From the Ministry of Pensions Hospital Service)*

THIS article is concerned with the records and observations on some particular bone and joint injuries which, we believe, will be of interest to readers. It is hoped that a further communication will record our experience of the treatment of soft tissue injuries, using the Stannard irrigation envelope. The review deals almost entirely with service men injured during training, or, together with the women, while in action on the home front. The majority of the patients were men of the army and the age groups were comparable to the classes which had been called up during the period under review. A few of the civilian air raid casualties belonged to the older age groups.

On account of the record filing system actually in operation, it has not proved feasible to obtain full details on every case; in many individual instances, treatment and evaluation of results have been complicated by repeated evacuations due to the exigencies of war. It is, however, possible to submit Tables I and II, of fractures and joint injuries treated in the course of the years 1941 and 1940, together with the anatomic distribution of these injuries. The relative incidence of fractures thus demonstrated is of interest.

We draw attention to the comparative infrequency of fractures involving the head and trunk in contrast to those of the extremities; the few with which we have had to deal have been managed on orthodox lines with satisfactory results. In the main, it can be stated that the problems are comparable to those met in dealing with civilian and industrial accidents. However, certain aspects have appeared to take on more importance in view of the strict evaluation of results of treatment as interpreted by terms of rapid return to full and arduous duties. Again, ambulatory treatment not only lessens the work of the hospital and its staff but also directly raises the morale of the patients, particularly during periods of enemy air activity.

*Fractures of the Upper Extremity.*—The age groups into which the majority of our patients have fallen are those in which two particular fractures typically occur, namely, the head of the radius and the waist of the carpal scaphoid. In addition to this, the active life and mechanical work have produced many injuries of the wrist and the fingers.

*Formerly Assistant in Surgery, British Postgraduate Medical School.

Received for publication, April 14, 1943.

TABLE I

| FRACTURES | 1941 | 1940 |
|---|---|---|
| *Head:* | | |
| Skull | 4 | 3 |
| Nose | 8 | 2 |
| Mandible | 2 | 3 |
| *Spine:* | | |
| Cervical | 2 | 3 |
| Dorsal | 4 | 2 |
| Lumbar | 3 | 1 |
| *Thorax:* | | |
| Ribs | 8 | 4 |
| Sternum | 0 | 1 |
| *Upper extremity:* | | |
| Clavicle | 6 | 7 |
| Scapula | 3 | 5 |
| Humerus | 8 | 5 |
| Forearms: | | |
| Radial head | 5 | 4 |
| Shafts | 5 | 6 |
| Wrist | 16 | 12 |
| Hand: | | |
| Scaphoid | 15 | 6 |
| Metacarpals | 13 | 7 |
| Phalanges | 15 | 10 |
| *Lower extremity:* | | |
| Pelvis | 4 | 2 |
| Femur | 5 | 10 |
| Patella | 4 | 3 |
| Leg: | | |
| Upper ends | 5 | 9 |
| Shafts | 16 | 16 |
| Ankle | 28 | 23 |
| Foot: | | |
| Tarsus | 4 | 3 |
| Metatarsals | 6 | 12 |
| Phalanges | 9 | 1 |
| Totals | 198 | 160 |

| DISLOCATIONS | | |
|---|---|---|
| Shoulder | 1 | 3 |
| Acromioclavicular | 3 | – |
| Sternoclavicular | 1 | – |
| Elbow | 4 | 2 |
| Wrist | 1 | – |
| Fingers | 1 | 2 |
| Hip | 3 | – |
| Totals | 14 | 7 |

*Fractures of the Head of the Radius.*—Although the number of fractures of the head of the radius has not been large, the management has been of interest in view of the divergence of opinion on the question and timing of operation. It has, as a rule, been found at operation that the injury is more extensive than the x-rays have suggested. Of seven cases of fracture of the radial head, one was complicated by concurrent dislocation of the humero-ulnar joint; four of the remainder showed slight cracks only, without displacement, and restoration of function was rapid. In our opinion, the indication for operation is any degree of displacement likely to cause irregularity of the radial

articular surface, which would in turn lead to a progressive osteo-arthritis. Where operation is decided upon, we consider that better results are obtained when it is carried out as early as possible, before any damage is done to the capitellar articular surface. The loss of power is slight, and in recent cases the ultimate range of movement obtained should be almost full. Five excisions of the radial head have been carried out, two of them for dislocation (one congenital).

*Fracture of Carpal Scaphoid.*—The relative number of these cases encountered has been remarkable and the incidence appears to be steadily increasing. The protracted nature of many has emphasized this, as at one time no less than eight were under treatment simultaneously. Of twenty-one cases encountered, five have been transferred elsewhere and three are still under treatment; the remaining thirteen have been returned to full duty. In four recent fractures (three waist, one tuberosity) immediate treatment, i.e., plaster of Paris immobilization for six weeks, has sufficed to ensure demonstrable union, both clinically and radiologically, and less recent fractures have required periods of fifteen weeks or more. After some weeks it appears that an untreated fracture forms a type of fibrous scar which it is difficult for the osteoblastic tissues to penetrate. It has, therefore, become our policy to operate immediately on the majority of these old, hitherto untreated, fractures, as long as necrosis is not perceptible and arthritic changes are not advanced. We have not encountered this until recently, when we saw two cases and propose to carry out arthrodesis of the wrist.

Four operations for bone grafting have been performed through a radial incision: one graft was taken from the tibia, the others from the olecranon; the operation was followed by plaster immobilization until clinical union was confirmed radiologically. In two of these patients complete union was obtained; a six-month-old fracture took three and one-half months; an eighteen-month-old fracture five months; the third patient has been transferred, and the fourth is ununited after five and one-half months.

*Acromioclavicular Dislocation.*—Although minor degrees of this condition have responded to strapping and physiotherapy, we have had two patients with persistent pain and impairment of function, in whom operative treatment was indicated. The main factors in maintaining the stability of the joint are the coracoclavicular (conoid and trapezoid) ligaments, and the operation performed here is directed to reinforce these rather than the acromioclavicular ligaments, which are quite secondary. Strips of fascia lata, cut with a fasciotome, are passed through the coracoid and clavicle, and secured with catgut. Both patients have made a complete recovery.

*Fractures of the Lower Extremity.*—The force required to fracture the pelvis or femur, or to dislocate the hip of a young adult, is usually

prodigious, and we have found that such injuries are almost invariably due either to the effects of high explosive or to motorcycle accidents.

In 1940, fractures of the shaft of the femur were treated by the method of continuous traction through a Steinmann pin over a Braun frame. The repeated air raids of the following winter emphasized the helplessness of patients undergoing this form of treatment, many of them already bomb victims, and we have since adopted a walking plaster spica treatment. By this method, the fracture is reduced under x-ray control on a table devised by one of us (A. G. O.), traction being applied both through the tibial tubercle and the calcaneus, with the hip and the knee joints flexed to 30 degrees (see Fig. 1). The position is maintained by a plaster spica extending from the axillae to the toes; the flexion of the hip and the knee preserves the extension and prevents rotation or angulation. These patients can be transported with minimal risk and are able to walk on a stirrup sometimes

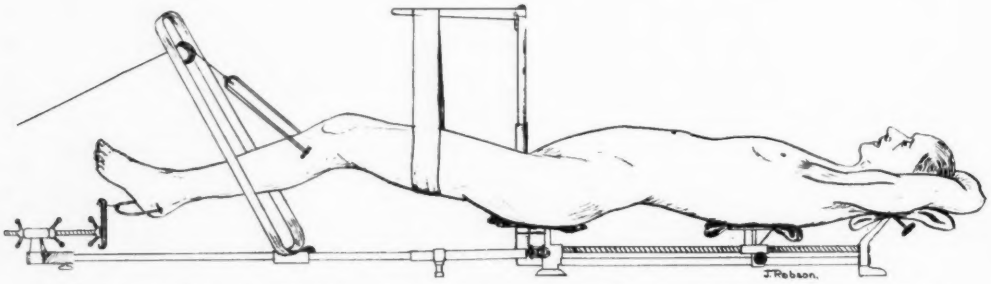


Fig. 1.—Method of maintaining reduction with double pin traction while applying plaster spica.

without crutches or even without sticks, within two or three days, if necessary. No final conclusion can be drawn from the few cases which we have treated ourselves, but two air raid casualties with fractures of the middle one-third produced callus in four to six weeks and were able to bear weight within nine weeks. The criticism that such immobilization causes stiffness of the knee was not confirmed in these men who within six weeks of the removal of the plaster had a knee flexion of more than a right angle. A third man with a compound supracondylar T-shaped fracture, with backward displacement of the lower fragments, required only eleven weeks before union occurred, and after another nine weeks of active physiotherapy had a range of 103 to 175 degrees and was steadily improving. Thus, apart from the good psychologic effect on these patients who are no longer helpless and immobilized, the functional results and duration of treatment appear to compare favorably with other more orthodox methods. Although only three cases have been quoted here, one of us (A. G. O.) has used this method of treatment in over twenty cases, which include some patients of the older age groups. Return of knee function is of course more rapid and complete in the younger patients.

This method of reduction and fixation takes us one hour or more to complete and radiologic assistance is essential. Therefore, we do not advocate carrying out this procedure while air raids are in actual progress, because not only may the x-ray apparatus be out of action as a result of electrical failure, but also because we have found it impossible to afford the necessary time when other more urgent surgical procedures may have to be undertaken. Accordingly, we have inserted a Steinmann pin through the tibial tubercle, under local anesthesia in the ward, and nursed the patient on a Braun's frame. This procedure deals with the emergency and takes only a few minutes. At our leisure on the following day the patient is transported in his bed to the theater where, under general or spinal anesthesia, a Böhler caliper is inserted into the calcaneus and the patient is transferred to the extension table. Reduction under x-ray control and plaster fixation are then carried out.

*Fractures of the Tibial Shaft.*—Recent observations on the prolonged disability due to this type of injury have been confirmed by us. The subcutaneous character of most of the bone means not only a restricted blood supply but also an increased tendency to compound (open) fracture, which may further delay recovery. From the point of view of management we divide such open fractures into those due to penetration by fragments of bone from within, and those due to foreign bodies penetrating from without, e.g., war injuries. Where possible, the "internal" type is treated by excision of the wound, introduction of sulfonamide, and primary suture; the leg is kept under traction by a Steinmann's pin through the calcaneus and raised over a Braun's frame until the wound is healed, when plaster is applied as in a closed fracture (to be described later). In cases of "external" penetration by foreign bodies, radical débridement is carried out, sulfonamide powder is introduced, and the wound lightly packed open with vaseline gauze, a closed plaster being then applied. If the amount of soft tissue damage is limited, e.g., as is more commonly found in the civilian type of compound fracture, primary suture is undertaken, but this is never done when there is any doubt as to the completeness of the excision, that is, after injuries due to high velocity projectiles.

For the reduction of closed fractures we have preferred vertical traction under x-ray control to the horizontal traction apparatus of Böhler, in which gravity tends to produce backward bowing, and is not used to assist the reduction. Traction is applied by Böhler's ice-tong caliper to the calcaneus or by fixing a stirrup to the retained Steinmann's pin in the case of the compound fractures. In the oblique and spiral fractures the unpadded plaster is extended well above the knee, although this does not appear to be indispensable in completely reduced transverse fractures below the middle one-third of the bone.

Although the latter have not the same tendency to slip as the former, it is our impression that callus formation is often much slower. In all cases, a minimum of ten weeks' immobilization in plaster has been required, and a troublesome complication has been stiffness of the forefoot and ankle when the plaster has been finally removed, due in part to the development of some degree of pes planus and in part to edema following the removal of the cast. In several instances recovery has been delayed for six weeks or more on this account alone. For this reason, after about eight weeks we replace the knee-to-toes plaster with another, incorporating a "slipper" (Figs. 2 and 3). These slippers consist of a leather sole covered with a layer of sorbo rubber. The posterior part of the slipper is incorporated in the plaster which stops

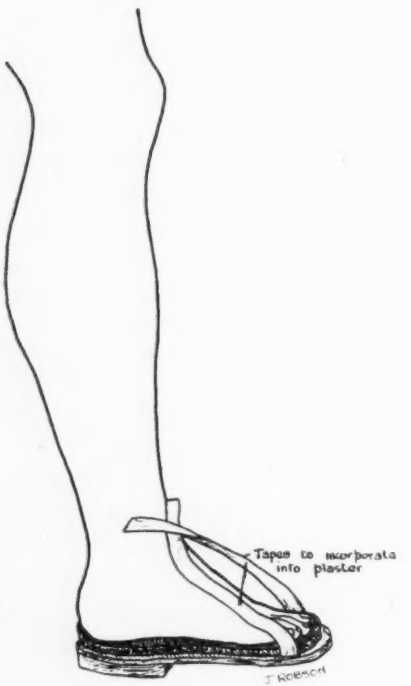


Fig. 2.

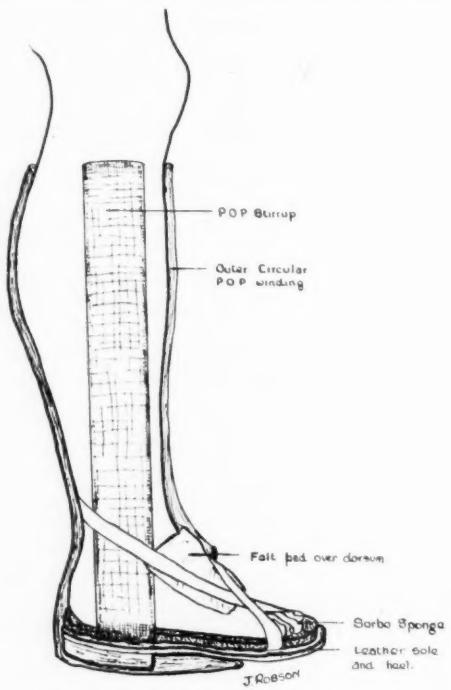


Fig. 3.

Fig. 2.—Sole to be incorporated in cast.

Fig. 3.—Sorbo and leather sole being incorporated in cast to permit active exercise of foot.

short at the midtarsal joint, allowing heel-toe walking and movement of the forefoot while immobilizing the ankle. In wet weather these can be protected by an "elephant boot." These slippers have proved to be of great value in accelerating the return of function. We have used them also in treating sprains and minor fractures of the ankle, where excessive immobilization is to be avoided. They are appreciated by patients who like to feel that they can use the foot despite the injury, and the active exercise maintains the tone of the intrinsic muscles of the foot, and assists the venous return from the limb.

Reduction of fractures has, of course, been confirmed by x-ray control, and here the Victor portable outfit has been very valuable. Fluroscopic screening is not only potentially dangerous to the operator but may be deceptive in many instances. We have found an ultrarapid developing technique an extremely useful alternative. This necessitates a small dark room immediately adjoining the theatre and, for instance, in bone grafting operations, sterile covers (e.g., small pillow slips) are used for the cassettes which can thus be handled by the surgeon without endangering the asepsis. By the use of an express developer the negative can be made ready for inspection on the viewing box alongside the surgeon within ninety seconds of the exposure—before, in fact, the surgeon has had time to rinse his hands and rearrange the towels. In grafting the scaphoid, for instance, the direction of the drill can be checked with absolute precision.

*Injuries of and Around the Knee Joint.*—A relatively large number of patients with injuries of and around the knee joint have been seen and treated during the period under review. This is to be expected because of the occupation and age group into which the majority of our patients fall. About one-half of the cases dated back their original injury to an accident sustained at football.

From Table II it will be seen that the majority of the injuries were other than cartilage lesions.

TABLE II

KNEE JOINT INJURIES

| | |
|---|---|
| 1. Traumatic arthritis* | |
| A. Direct contusion | 7 |
| B. Torsion injuries | 21 |
| 2. Internal lateral ligament injuries | 14 |
| 3. External lateral ligament injuries | 2 |
| 4. Cruciate ligament injuries | 6 |
| 5. Quadriceps insufficiency | 6 |
| 6. Thickened pad of fat | 2 |
| 7. Fractures | 16 |
| 8. Loose bodies | 3 |
| 9. "Painful knee" | 1 |
| 10. Osteoarthritis | 2 |
| 11. True internal cartilage injuries | 16 |
| 12. Internal cartilages (operated elsewhere and with recurrent symptoms) | 10 |
| 13. External cartilages | 5 |
| 14. Cysts of external cartilage | 8 |
| Total | 119 |

*The term traumatic arthritis is used in preference to the more usual term synovitis because it is visualized that the inflammatory processes of resolution following injury probably implicate other joint tissues.

The primary acute cases have presented little difficulty in diagnosis, but we have been impressed by the difficulties in making an accurate diagnosis in the patients who have suffered from previous disability in the same knee. This seems to have been emphasized by our own operative findings in cases where cartilage lesions have been suspected,

but have not been found; with every patient careful and repeated examinations have been made and a full staff discussion carried out before operation has been undertaken. Further emphasis has been laid by the ten patients who have been admitted here because of recurring symptoms after meniscectomies performed in other hospitals.

It would seem to us that the majority of difficulties in accurate diagnosis have arisen chiefly in patients with traumatic arthritis and associated quadriceps insufficiency, who have been incompletely treated at the time of the primary injury. We cannot, therefore, emphasize too strongly the importance of an accurate diagnosis in the first instance, and thoroughly adequate treatment before the patient passes from the medical officer's supervision.

We have treated the majority of patients with acute traumatic effusions into the knee joint by aspiration as soon as possible under local anesthesia. Varying amounts up to 100 c.c. of bloodstained glairy effusion have been found, and the proportion of blood, as judged by the naked eye, has varied. Generally, it has been considerable, and it appears to us that if such an effusion is left to absorb, the ligaments might stretch under the tension, and the synovial membrane may become thickened with fibrinous deposits, new blood vessels, and inflammatory cells. If this occurs, then together with the associated loss of tone of the quadriceps, a varying degree of instability of the knee joint will result and further repeated intra-articular damage is liable to follow.

After careful clinical and radiologic examination, the aspiration has been followed by application of a firm Robert-Jones bandage (preferably using crepe bandages). Physiotherapy and active exercises, especially weight lifting, have then been carried out under careful and continual observation. For the first few days the bandage is left in position and active exercises are carried out with the knee joint extended. After this, the bandage is removed only during the periods of physiotherapy, and weight lifting from the bent knee position is begun. The bandage is reapplied and remains in position for the patient to begin walking after a week. If care has been taken to treat the quadriceps muscle the bandage can usually be dispensed with after a further week. In spite of this, we have found that it is often six weeks before we have been able to assure ourselves that the man's knee is fit enough to stand up to the rigors of Army life.

We maintain that this type of knee joint injury should be treated with special care and continued observation and encouragement in order to lessen the incidence of recurrence with its increasing difficulty in diagnosis, and the dangers and bad ultimate results which may follow unnecessary operative exploration of the knee joint for doubtful cartilage injuries.

In partial injuries of the medial collateral ligament, we have been interested to note the prolonged residual tenderness, sharply localized, most frequently over its femoral attachment, which frequently lasts six weeks or longer. In addition to physiotherapy, active exercises and wedging of the inner side of the boot, we frequently have infiltrated the injured part of the ligament with novutox or planocaine. In about one-half the cases, the residual tenderness has been permanently abolished, but this procedure has not proved as completely satisfactory as we had hoped.

An unusually high incidence of cysts of the external cartilage have been seen and although the etiology of these cysts is not necessarily or exclusively traumatic, we have included them in this review because the symptoms which led the patients to seek treatment commonly followed some form of trauma, often, it is true, quite mild in nature. Of eight cysts seen, six have been excised, together with the associated cartilage, through a large curved incision laterally over the knee joint. The rapid and complete recovery made by these men has been impressive. The convalescence is shorter, and the result of the operation seems to be more satisfactory, than in other types of knee joint injury.

## SUMMARY

A review is given of the anatomic distribution of fractures and joint injuries encountered during the first two years of the war. Attention is paid to injuries commonly causing protracted disability, viz: fracture of the carpal scaphoid, fracture of the head of the radius, and dislocation of the acromioclavicular joint.

The methods used to overcome these difficulties are summarized and the reasons given for

(1) Early excision of the radial head where irregularity of the articular surface may lead to a progressive arthritis.

(2) Grafting fractures through the waist of the scaphoid where they have been untreated for six months or longer.

(3) Reconstructing the coracoacromial, rather than the acromioclavicular ligaments in severe displacements of the acromioclavicular joint.

In fractures of the lower limb, emphasis is laid on the importance of ambulatory treatment, both for the psychologic benefit of the patient and to facilitate his transportation. Details are given of a method used in reducing fractures of the femoral shaft prior to the application of a plaster spica.

Distinction is made between the different types of compound fractures and their management, together with some views on the treatment of fractures of the tibial shaft.

Express x-ray developing is recommended as a valuable and accurate alternative to screening during manipulations or bone grafting operations.

An account is given of our experiences of knee joint injuries. Table II stresses the comparatively large number encountered, and the small proportion of true cartilage lesions. The majority of patients sent in with suspected cartilage lesions were cases of traumatic arthritis following a wrench of the joint. They had received inadequate treatment at the time of the original injury and had, as a result, developed insufficiency of the quadriceps. This had led to repeated trauma which prolonged the duration of disability and increased the difficulties of accurate diagnosis and proper treatment, hence, the vital importance of early accurate diagnosis and correct and adequate treatment is stressed.

The late Dr. H. Lightstone, D.G.M.S., ministry of pensions, kindly gave us permission to publish this article. We record our thanks.

# THE EFFECT OF SULFUR COMPOUNDS ON BLOOD CLOTTING*

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## INTRODUCTION AND PREVIOUS LITERATURE

IN A previous communication,[1] a simple test of the clotting mechanism was described, which briefly consists of the study of the individual's response to a small, test dose of heparin. The coagulation time of capillary blood is determined before, ten, twenty, thirty, and forty minutes after the intravenous injection of 1 c.c. (10 mg.) of purified heparin. Dry, standard-sized capillary tubes are used for this purpose. The individuals tested readily fall into hyporeactors, normal reactors, and hyperreactors. The pattern of such a heparin curve remains surprisingly constant in the same individual as long as seventeen days.[1]

The heparin-tolerance curve permits a study of various factors which influence coagulation of blood. In this report the effect of sulfur compounds on the clotting mechanism is presented.

Heparin, itself, is a mucoitin-polysulfuric acid and its anticoagulant action is in direct proportion to its sulfur content.[2] That sulfur radicals play an important part in intracellular oxydation has been widely recognized since the isolation of glutathione from the tissues by F. G. Hopkins.[3] The active principle of glutathione, cysteine seems to be the intracellular carrier of oxygen.[4]

Both cysteine and methionine, two sulfur-containing amino-acids, have been stated to prolong coagulation and bleeding times by Sterner and Medes.[5] Carr and Foote[6] felt that the accumulation of these sulfurated amino-acids in the plasma of patients suffering from obstructive jaundice explained their tendency to bleed.

The metabolism of such sulfur compounds could be minimized by a low protein, high carbohydrate diet. Of all the thiol compounds, glutathione seemed most potent in its inhibiting action on thrombin.[7] This was only true, however, in a neutral or acid medium. Rabinowitz[8] stated that alteration of clotting time was directly dependent upon the amount of thrombin inactivated by cysteine. Curiously enough, this author advocated cysteine and methionine to control spontaneous bleeding and to restore clot retraction in hemorrhagic purpura. Putman and Hoefer,[9] after carefully conducted animal experiments, gave cysteine to patients suffering from multiple sclerosis and obtained in seventeen out of twenty-three instances a prolongation of the clotting time. When cysteine was first administered to patients at St. Luke's Hospital, we were unaware of this significant experimental and clinical study.

*Aided by a grant of Hoffmann-La Roche, Inc., in Nutley, N. J., Mr. Vincent McCue rendered all technical assistance.

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Sodium thiosulfate has been advocated for several years in the treatment of Buerger's disease or for the prevention of phlebitis. Rabinowitz[10] and Rabinowitz and Kahn[11] suggested this drug, combined with iodine, to correct disturbance in the phospholipin metabolism, which they found to exist in thromboangiitis obliterans. Bancroft and his associates[12] have extensively investigated the use of sodium thiosulfate in thrombophlebitis and concluded that the incidence or the duration of thrombophlebitis can be materially reduced by the use of this drug combined with a diet low in fats and proteins. In a series of detailed investigations on the changes in the blood in thromboangiitis obliterans, Theis and Freeland[13] stated that inorganic sulfur compounds produce a marked increase in the oxygen capacity and content of the circulating blood. In the active stage of Buerger's disease, they found the oxyhemoglobin to be in an inactive state. The catalytic action of glutathione corrected this anomaly. Their data demonstrated that the administration of inorganic sulfur increased both the reduced and oxydized form of glutathione in the blood.

This partial survey of the previous literature supports the use of sulfur compounds to raise the level of the oxygen catalyst in the blood and tissues and thus influence the oxydation-reduction system in the blood. With the introduction of sodium tetrathionate, which has a more prolonged action and is excreted more slowly than sodium thiosulfate, Theis and Freeland[13] have described a successful correction of the disturbed chemistry in Buerger's disease. Clinically, there can be no doubt about the beneficial influence of intravenous sulfur compounds, especially in migrating phlebitis (own observations). Observations are here reported on the effect of sulfur compounds on heparin tolerance. If sulfur really prevents or inhibits the formation of thrombi, its effect on the reaction to heparin should be noticeable.

## METHODS OF INVESTIGATION

Heparin tolerance curves were determined (1) before and ten to thirty minutes after a single dose of sodium thiosulfate or tetrathionate, (2) before and after a course of twelve biweekly injections of sodium tetrathionate, (3) before and after a single dose of cysteine given by mouth, (4) before and after two weeks of oral administration of cysteine. The dosage employed was: 15 gr. (1 Gm.) of sodium thiosulfate and 10 gr. (0.6 Gm.) of sodium tetrathionate given intravenously. Fifteen grains (1 Gm.) of cysteine were given by mouth. For the prolonged administration this dose was given three times a day after meals. No attempt was made to restrict or acidify the diet.

## RESULTS

1. *Single injections of sodium tetrathionate:* In every single instance the injection of sodium tetrathionate has increased heparin sensitivity, whether the patient was a hypo-, hyper-, or normal reactor. Fig. 1

shows the curves of the reactions of four patients. It is interesting that in Case 2, where the reaction to heparin was normal, the greatest exaggeration of response was obtained after the injection of sulfur. The least response was obtained in Case 4. The patient in this case had multiple embolic phenomena and had demonstrated clinically his marked tendency to thrombosis. The curves of another group of three patients are shown in Fig. 2. Again, one of the patients (Case 3)

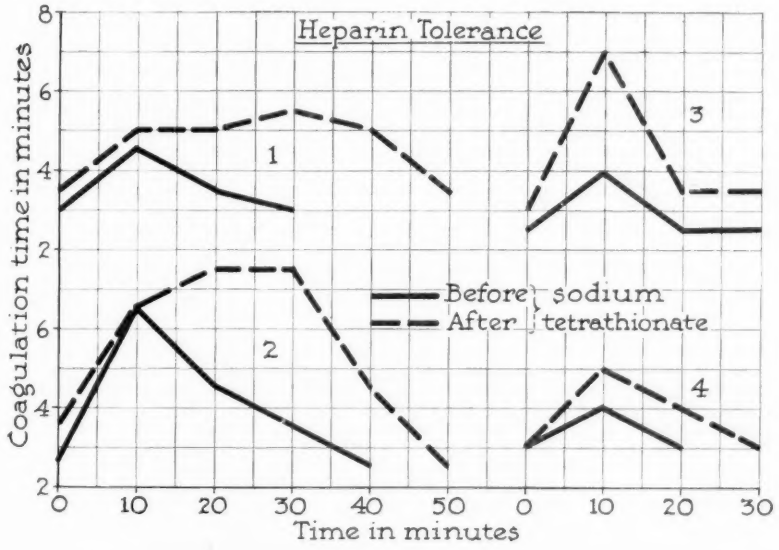


Fig. 1.—Case 1 is that of Marvin M., with migrating phlebitis as a symptom of Buerger's disease. Note the marked prolongation of the effect of heparin after the sulfur compound has been given.

Case 2 is that of Frank M., who was suffering from essential hypertension. He had a normal clotting mechanism and showed a marked response to heparin ten minutes after sodium tetrathionate had been given.

Case 3 is that of F. B., who had a chronic, recurrent type of Buerger's disease and whose heparin response was markedly improved by sodium tetrathionate.

Case 4 is that of LeRoy M., who had multiple emboli following coronary thrombosis, one of them resulting in gangrene of the left lower extremity. His response to sodium tetrathionate was very small, indicating a marked clotting tendency.

showed only a small response to sodium tetrathionate. This 45-year-old man, suffering from a subacute stage of Buerger's disease, showed a diminished response in that his coagulation time returned to normal at twenty minutes after the injection of heparin. The injection of sulfur improved this response only very slightly. He had not stopped smoking. As Theis has shown, smoking and sodium tetrathionate antagonize each others action.[13]

2. Another group of patients received twelve injections of sodium tetrathionate, given twice a week. The heparin tolerance was determined before, during, and at the completion of the treatment. Note that the heparin tolerance, which has diminished at the start, improved as early as the third day of the treatment (Fig. 3). In the next graph (Fig. 4) the tolerance curves of three patients are shown who have received twelve injections of sodium tetrathionate; in the case of A.B.

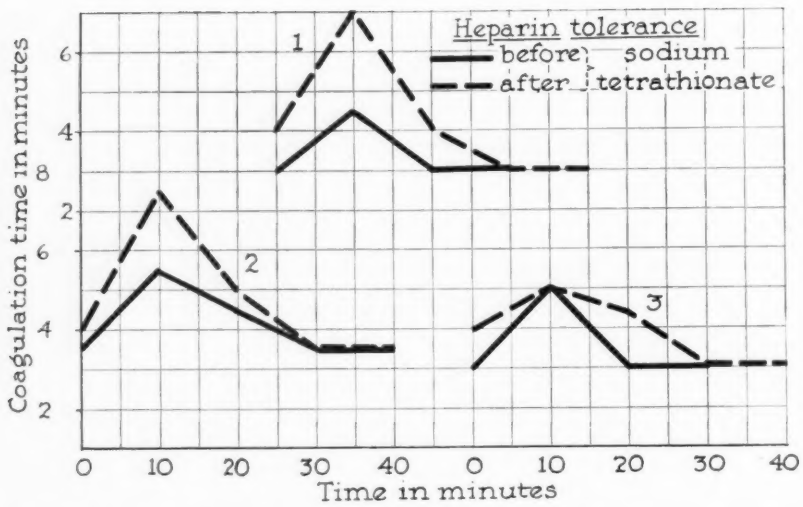


Fig. 2.—Case 1 is that of Thomas McM., 60 years old, with a coronary thrombosis occurring one year previously. The flat heparin curve improved markedly after sulfur.

Case 2 is that of Ida de G., aged 61 years, with a diabetic arteriosclerosis. A normal tolerance curve, greatly improved after sulfur.

Case 3 is that of Dempster S., 45-year-old man, suffering from a subacute stage of Buerger's disease. There was very little response to sodium tetrathionate. The patient was unable to stop smoking.

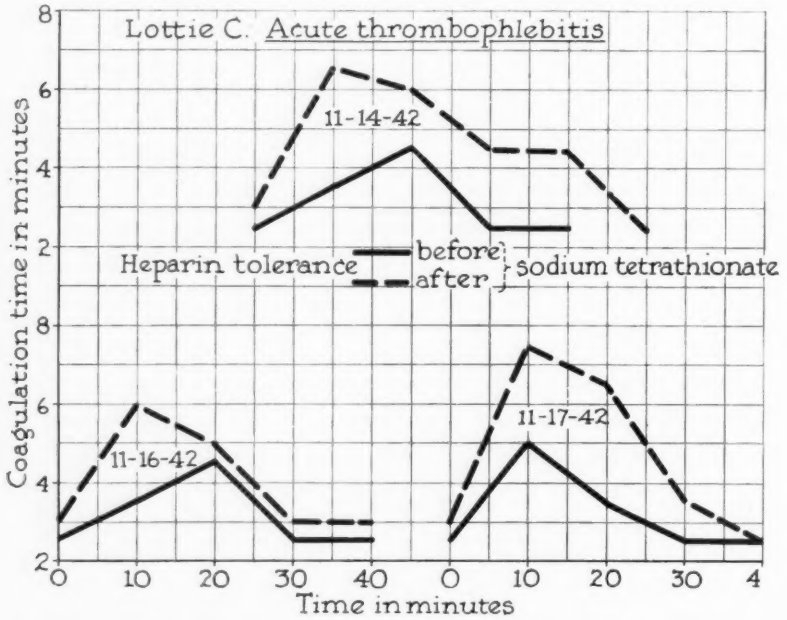


Fig. 3.—Heparin tolerance before and ten minutes after the injection of 0.6 Gm. (10 gr.) of sodium tetrathionate. The patient is Mrs. Lottie L., aged 54 years, who had an acute thrombophlebitic induration of the left lower leg. The first two heparin-tolerance tests show a flat curve, whereas the third one is within normal limits. In all of the three experiments the sulfur compound markedly increased the response to heparin. Given without heparin, sodium tetrathionate has not prolonged capillary coagulation time.

an additional determination was possible after six injections. In the case of Harold B., the sulfur compound produced a "hyperreactor" response,[1] whereas originally this patient's response was abnormally low.

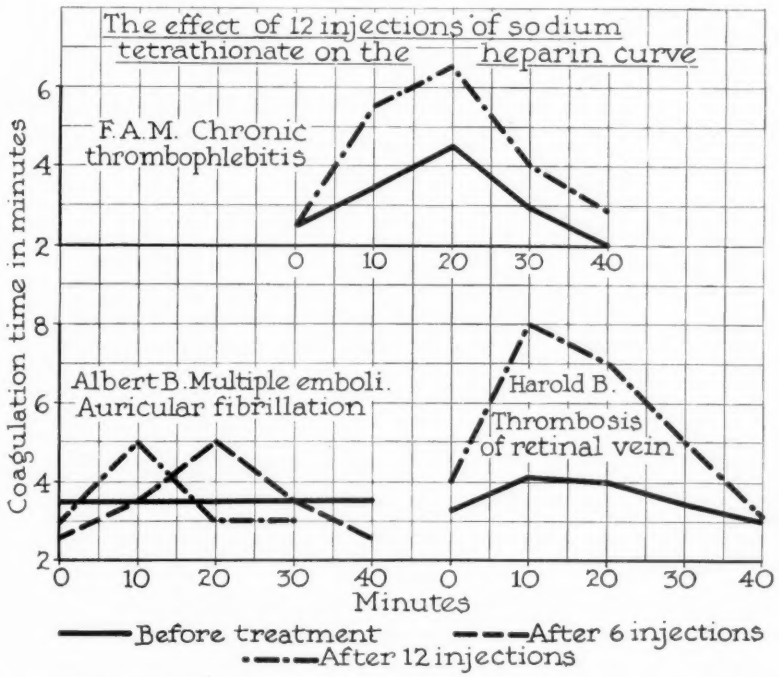
The effect of 12 injections of sodium tetrathionate on the heparin curve
F.A.M. Chronic thrombophlebitis
Albert B. Multiple emboli. Auricular fibrillation
Harold B. Thrombosis of retinal vein
Coagulation time in minutes
Minutes
Before treatment
After 6 injections
After 12 injections

Fig. 4.—Heparin curves before and after twelve injections of sodium tetrathionate. In the case of F. A. M. a somewhat flat curve became high. In the case of A. B. the first curve was quite flat; it improved after six injections and still more after twelve injections, but never has become normal. This patient continues to have emboli from the left auricle into both lower extremities, into the left arm, and two to the brain. The most striking response was obtained in the case of Harold B., who has had several thromboses of the retinal vein. While his initial response was very low, the heparin sensitivity increased considerably and placed him in the hyperreactor group. One peripheral artery was occluded. He has had no further vascular episodes.

3. After a number of single doses of cysteine it was impossible to observe any change in the heparin curves. These determinations were made between 15 and 120 minutes from the time of the oral dose, but failed to show any effect.

4. In a group of ten patients cysteine hydrochloride was given in three daily doses of 15 gr. (1 Gm.) after meals for two weeks. It was impossible to observe any clear-cut effect on the heparin tolerance. In one patient, Anton K., suffering from Buerger's disease, who was admitted to the hospital with a flat heparin-tolerance curve, the curve was restored to normal in twenty-four hours after three doses of cysteine. However, other measures, such as increased fluid intake and abstinence from tobacco, may have been responsible for this effect. Further doses did not increase heparin sensitivity. In no other patient was any change observed. In A. K. cysteine was given, after dicoumarol had lowered the prothrombin level to 40 per cent of normal. During the

administration of cysteine, which was maintained for two weeks, the prothrombin-level returned to normal at a rate which it usually does when dicoumarol is discontinued. In addition, the patient who had had multiple peripheral and one cerebral embolus previously, suffered another cerebral embolus while taking cysteine and after having taken a total of 450 gr. (30 Gm.) by mouth in ten preceding days.

### COMMENT

The results indicate that sulfur compounds given intravenously definitely increase the patient's response to heparin. It is likely that both the reduced and oxydized forms of glutathione are increased by the injection of sulfur,[13] but the obvious change in the clotting mechanism is that the patient becomes sensitive to heparin.

While it is impossible to observe any change in the clotting mechanism after oral ingestion of sulfur, further trial of this type of medication is still in progress. It may be that by placing the patient on a low protein and low fat diet[6, 12] some effect could be obtained. Also, if the cysteine medication tends to accumulate glutathione in the blood, this catalyst inhibits thrombin only in an acid or neutral medium.[7] The oral administration of ammonium chloride or nitrate might prove useful.

Another group of observations might be cited. Patients receiving sulfonamide drugs have shown a remarkable response to heparin. The first patient on whom this reaction was observed had subacute endocarditis and was receiving 120 gr. (8 Gm.) of sulfapyridine daily. A heparin curve showed a marked increase over the normal pattern (Fig. 5). This finding is important since patients suffering from subacute bacterial endocarditis are sometime given heparin in the customary safe doses and hemorrhages still occur. In I. C., who had an ascending facial infection with nasal and periorbital edema, and was receiving sulfanilamide, not more than three injections of 50 mg. of heparin produced nasal hemorrhages. Certainly, caution ought to be observed in the dosage of heparin when sulfonamide drugs are given.

The action of the intravenously given sodium tetrathionate is very encouraging and we are now using an 0.6 Gm. ampule to each 1000 c.c. of intravenous fluid (dextrose or salt) given postoperatively. In the first communication on heparin tolerance it was shown that the heparin curve becomes flat after major operations for the first two to three days. My associates and I are studying different measures to change this clotting tendency. Obviously, heparin and dicoumarol will never be administered preventively to all patients, but the inexpensive and nontoxic sodium tetrathionate is now in routine use on our surgical service. It will necessarily take many hundreds of cases before a possible decrease of postoperative thrombosis can be observed.

In addition to its use for postoperative patients, sodium thiosulfate has been used for many years on my service in the acute and subacute stages of Buerger's disease. It was used with the same idea that

prompted us to advocate small, subreactionary doses of triple typhoid vaccine in Buerger's disease, namely, to desensitize the patient to an unknown specific sensitizing agent.[14] The work of Theis and Freeland[13] has given an entirely different explanation for the beneficial effect of

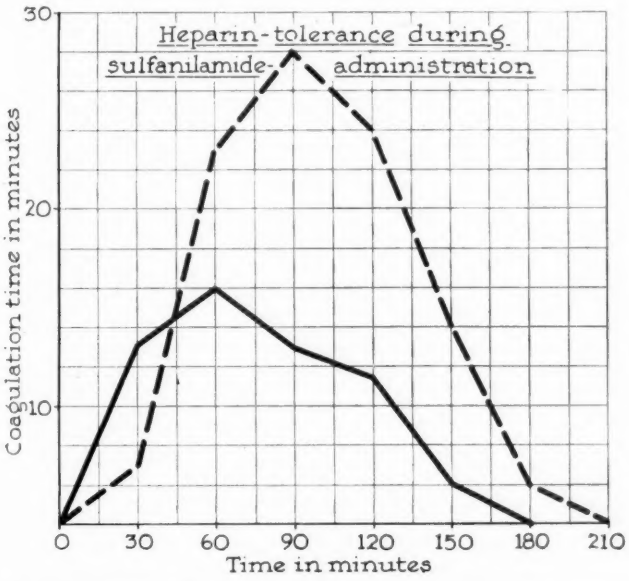


Fig. 5.—Heparin curves after the intravenous injection of 5 c.c. (50 mg.) of heparin; average curve of normal response of four patients. This is the usual therapeutic dose, which has been given to more than fifty patients. Note that the peak of the rise occurs at the first hour and does not exceed fifteen minutes. In the case of M. R., a 26-year-old man suffering from rheumatic heart disease with a superimposed bacterial endocarditis and receiving 120 gr. of sulfapyridine, a considerable increase in the reaction to heparin was obtained. At one and one-half hour after the injection of heparin, the coagulation time rose to twenty-eight minutes. This is a dangerous level, which has never been obtained with the 5 c.c. dose. Further observations are being made on the augmenting effect of sulfonamide drugs on the action of heparin. The sulfapyridine level was 4.2 mg. per 1000 c.c. of blood on the day of the test.

sulfonamide drugs. There can be no doubt that in the acute stages of Buerger's disease the intravenous use of sulfur has given surprising results. Thus, in migrating phlebitis one can observe the rapid absorption of the hot, red periphlebitic exudate in a few days. It has been our custom to give a daily injection of sodium tetrathionate to hospitalized patients for two weeks, then follow it with biweekly injections for six weeks, and a single injection once a week for another six weeks.

There is, however, an urgent need for a safe, inexpensive drug affecting the clotting mechanism, which could be given by mouth for a prolonged period, without daily control of prothrombin times, which must be done if dicoumarol is to be given safely. Cysteine, as we have given it in this group of patients, has not been effective. Sulfonamide drugs obviously should not be given for such a purpose. Whether an acid producing, low protein, low fat diet combined with cysteine can fulfill our need is next is to be tried.*

*In preliminary observations no effect was noted when the diet and ammonium chloride were added to the administration of cysteine.

SUMMARY

With the help of a simple test of the clotting mechanism, namely the determination of the heparin tolerance of the patient, the effect of intravenous sulfur medication was studied. Sodium tetrathionate was found to increase definitely the patient's response to heparin after both single and repeated doses. The use of this drug for the prevention of postoperative thrombosis and for the acute stages of Buerger's disease, in which the heparin tolerance is poor, is definitely worth while. No simple, safe method of administrating sulfur by mouth for the same purpose has yet been found.

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# THE EFFECT OF HEPARIN ON EXPERIMENTALLY PRODUCED VENOUS THROMBOSIS

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THE scope of this communication is limited to the effect of heparin on experimentally produced venous thrombosis. Only a succinct discussion of the pertinent features concerning the mechanism of thrombus formation will be given here, as they have been considered extensively in numerous articles in the literature. It is a well-known fact, definitely established by experimental and clinical research, that the combination of trauma to the endothelial lining of a blood vessel and retardation of circulation in the region of injury is sufficient to effect local thrombus formation. This phenomenon is based on the principle that injury to the blood vessel sets free thromboplastin, and that the latter in turn converts prothrombin into thrombin. The free thrombin converts fibrinogen in the presence of calcium into fibrin and a clot is formed. The reason that blood does not clot intravascularly, is that no thromboplastin is available to convert the prothrombin to the active ferment thrombin. The formation of such a clot is hastened if the local circulation is retarded. On the basis of this knowledge one can produce experimentally an intravascular clot by the simultaneous injury of the endothelium and slowing of the local circulation. It was also shown by Best[1] that heparin may act both as an antithrombin and as an antiprothrombin in the prevention of clot formation, and that some as yet incompletely identified factor, or factors, present in blood serum is necessary for these actions.

In a series of experiments previously performed by one of us (J.R.)[2] it was shown that a forcible pull on a vein sufficient to injure its endothelial lining resulted in local clot formation. Furthermore, when the vein was partially constricted at the site of injury so as to retard the local flow of blood, the clot formed more promptly. Murray, Jaques, Perrett, and Best[3] utilized a somewhat similar procedure in their study of experimental thrombosis in dogs. They made no attempt, however, to retard the flow of blood at the site of injury, and this may account for a certain percentage of failures which they encountered in their experiments. The technique which these investigators employed may be summarized briefly as follows: A small piece of silk thread was passed through the lumen of a vein for a distance of about three-

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quarters of an inch and the vein crushed against the thread between the jaws of artery forceps. In this way not only the endothelial lining was injured but all the remaining coats of the vessel were equally traumatized. In another series of experiments performed by the same workers, chemical agents such as sodium ricinoleate were used to induce local clotting. These sclerosing agents injure the endothelium to the extent that a local clot will form.

Two problems confronted us in this study. First, would the injection of heparin prevent the formation of an intravascular clot if administered prior to injury of the vessel wall, and second, is heparin effective in causing the solution or disappearance of a clot once the latter has been formed? On this basis, the following experiments were carried out.

*Experimental.*—Before proceeding with the experiments it was found necessary to study the effect of heparin on the coagulation time of the blood of normal animals. Rabbits weighing 2 to 3 kg. were used. The coagulation time was determined by drawing samples of blood from the ear vein into very fine capillary glass tubes which were broken at regular, short intervals of time, and observed for the appearance of a fine, fibrinous thread. According to this technique the coagulation time of the normal rabbit's blood averaged three to four minutes.

The heparin used was furnished* to us in the form of Liquaemin solution. One cubic centimeter of the solution contained the equivalent of 10 mg. of highly purified heparin. In each of the succeeding experiments with liquaemin 1 c.c. of the anticoagulant was diluted with 10 c.c. of saline solution before it was injected into the ear vein of the rabbit. It was found that the intravenous injection of this amount of anticoagulant prolonged the coagulation time of the rabbit's blood for several hours.

*Control experiments:* In the following series of experiments the animal was injected with 1 c.c. of liquaemin diluted with 10 c.c. of saline and samples of blood were withdrawn at regular intervals in order to determine the effect of the drug on the coagulation time. An analysis of this study disclosed the following facts. Blood withdrawn 10 minutes after the injection of liquaemin remained fluid for more than ten hours. When removed one-half hour later, clotting took place after six hours. At the end of one hour, the clotting time was shortened to four hours, and at the end of five hours the clotting time returned to normal, namely three to four minutes. These results are represented graphically in Chart 1, and were substantially the same in several animals used as controls. It would appear from the experiments recorded here that in order to keep the blood of the animal fluid, it would be necessary to reinject the anticoagulant at least once every four or five hours.

*Furnished by Roche-Organon, Inc., Roche Park, Nutley, N. J.

*Technique of producing a venous clot by injuring the vessel wall and slowing the local circulation:* Rabbits averaging 2 kg. in weight were anesthetized by inhalation of ether. Under aseptic conditions a midline incision was made through the neck and both jugular veins were exposed. In some experiments both veins were used while in others one was used as control and the other for the actual test. After the vessel was liberated for a distance of about 2 or 3 cm., it was grasped on either side between the thumb and index finger of each hand and forcibly pulled so as to injure the endothelial lining. It was then partially constricted at the site of injury by tying a loose ligature around it, care being taken that the blood continued to flow through the narrowed lumen, although less freely. This procedure was found effective in producing an intravenous clot in each experiment.

*Control clot experiments:* In six rabbits the jugular veins were injured according to the technique described and the lumen of the vessels narrowed. At the completion of this procedure the wound of the neck was closed by first suturing together the divided fascia over the vein, and then the skin wound was closed with interrupted silk sutures. The animal was allowed to recover from the operation and at the end of twenty-four or forty-eight hours the wound of the neck was reopened and the injured veins exposed. At this time the veins were found occluded for a distance of about ½ to 1 cm. by a loosely adherent red clot. A portion of the vein containing the clot was excised and placed in 10 per cent solution of formalin for sectioning. Microscopic examination of the vein showed it to be occluded by a thrombus composed for the most part of a marginal zone of blood platelets adherent at one point to the endothelium of the vein. The rest of the clot was made up of a fine network of fibrin enmeshing numerous red blood cells and scattered leucocytes (Fig. 1).

*Experiments with liquaemin:* In six experiments 1 c.c. of liquaemin diluted in 10 c.c. of saline solution was first injected into the rabbit. The jugular veins were next traumatized as previously described, the lumen constricted with a loose ligature, and the wound closed. After four days the neck wound was reopened and the veins examined. It was found that in two rabbits the traumatized veins were occluded by a thrombus seen on both gross and microscopic examination. In the other four rabbits no gross or microscopic evidence of local thrombosis was observed. The injured endothelium had regenerated and there was no break in the continuity of the lumen. (Fig. 2).

In a series of experiments liquaemin was given to the animal both preoperatively and postoperatively. Six rabbits were injected with 1 c.c. of liquaemin diluted with normal saline solution and immediately after, the neck was opened through a midline incision, both jugular veins were exposed, traumatized, and their lumina constricted. Following the operation the animals received liquaemin injections in 1 c.c.

doses twice daily for periods ranging from two to five days. At the completion of the period of liquaemin administration, the animals were reoperated upon and the traumatized veins examined. It was then found that none of the animals showed any evidence of local clot formation both on gross and microscopic examination. It was also evident that the endothelium had regenerated at the site of the injury.

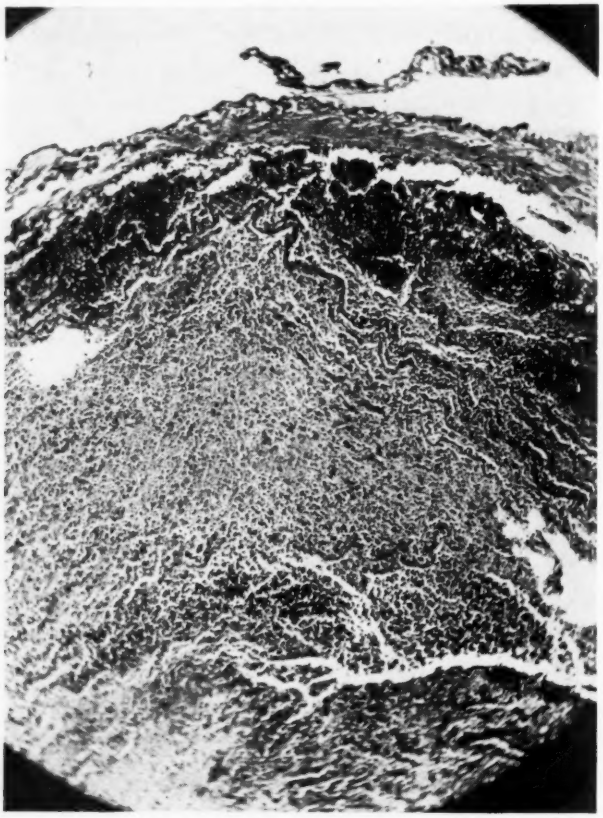

Fig. 1.—Control experiment; the lumen of the vein is occluded by a typically formed platelet thrombus.

From these observations it may be concluded that the administration of liquaemin both before and after injuring the vessel wall keeps the circulating blood fluid and prevents the formation of a local clot. At the end of four or five days the injured endothelium regenerates completely and thrombus formation does not follow. Animals receiving only a preoperative injection of liquaemin may or may not develop local thrombosis, although in the majority of instances it appears that a single injection of liquaemin is sufficient to prevent clot formation in the injured vessel. Somewhat different results were reported by Murray and his associates[3] in their experiments with heparin in dogs. These workers administered the heparin either as a single dose or in the form of a continuous infusion for seventy-two hours following the injury to

the vein. They found that, "in animals where only a single dose of heparin was injected before traumatizing the vein, twelve of the thirteen veins used were completely filled with thrombus and clot and the remaining one was partly occluded. To be effective, the vein had to be removed before the effect of heparin was worn off. In those experiments in which the animal was maintained under the influence of heparin for some time after injuring the vein the incidence of obstruction by thrombus formation was very small."

Fig. 2.—Animal received a preoperative injection of liquaemin; note the absence of clot in the lumen and regeneration of the endothelial lining.

The findings of Murray and his co-workers are not entirely in keeping with our data for several reasons. First, we have found it unnecessary to keep the animal continuously under the influence of the anticoagulant in order to prevent clot formation in the traumatized vein. As has been shown, a single preoperative injection of liquaemin was sufficient to prevent thrombosis in four out of six rabbits similarly treated. Second, in the series of experiments where the animals were injected with the anticoagulant both preoperatively and postoperatively, but after long intervals instead of continuously (twice daily), none had developed a local clot. In this respect, therefore, our findings are in

contrast to the findings of Murray and his associates and may be explained perhaps on the basis that there exists a difference in potency between the anticoagulants used in the individual experiments, or that the different types of animals used may be a factor. It is conceivable that one type of animal may be more responsive to the effect of the drug than another animal.

Fig. 3.—Experiment in which the vein was traumatized and a clot allowed to form; this was followed two days later by repeated injection of liquaemin in 1 c.c. doses twice daily for a period of six days. Note the complete disappearance of the clot and regeneration of the endothelial lining.

*The Effect of Liquaemin on the Formed Thrombus.*—In the following series the jugular veins were first traumatized in the manner described, the lumina were constricted, and a clot was allowed to form. On the second postoperative day the wound of the neck was reopened and the injured veins examined. It was then found that both veins were occluded by loose thrombi. A portion of one of the veins bearing the clot was removed for microscopic study and served as control. The constricting ligature was removed from the other vein which was otherwise left undisturbed. The animals were then injected with liquaemin in 1 c.c. doses twice daily for a period of five to six days. At the end of this time the animals were reoperated upon and the remaining vein removed and examined. It was then noted that the clot previously found occluding the vessel had completely disappeared in four of the

five animals under observation. Microscopically, the lumen of the control was occluded by a typical platelet thrombus. The veins of four of the animals that were injected with liquaemin showed no microscopic evidence of thrombus formation. In the remaining animal, the vein was partly occluded by a retracting clot. The endothelium of the vessel of the heparinized animal had regenerated at this time and the continuity of the lumen was re-established, (Fig. 3). It would appear then that liquaemin can cause the solution or disappearance of a thrombus if administered in the early stages of its formation.

Six rabbits were subjected to the same procedure as described here, excepting that the injection of liquaemin did not begin until the third postoperative day. In three of the animals no clot was found in the vein either on gross or microscopic examination. In one animal the vein was partly occluded by a retracted clot and in the remaining two animals the entire lumen was filled with a thrombus.

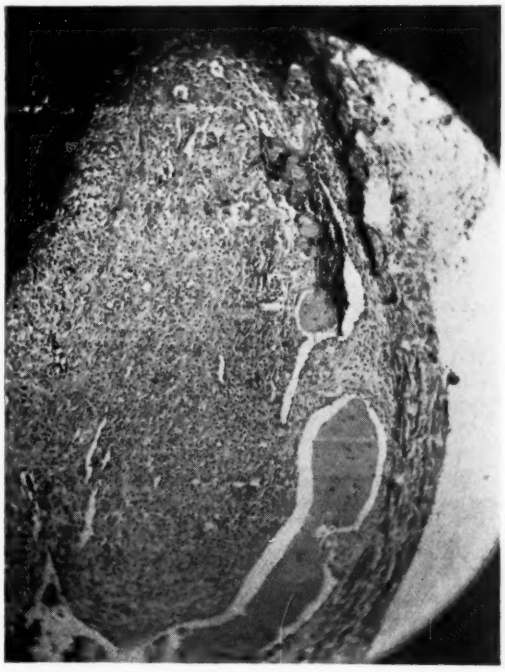

Fig. 4.—Experiment in which liquaemin was not administered until the sixth postoperative day. The clot had undergone complete organization with some recanalization; liquaemin had no effect in causing the disappearance of the thrombus.

In four rabbits the injection of liquaemin did not begin until the sixth postoperative day. At this time it was administered in 1 c.c. doses, twice daily, for a period of eight days, at the end of which time the animals were reoperated upon and the veins examined. It was then found that the veins in the entire series were occluded by an adherent thrombus. On microscopic examination the vein in each instance was occluded by a partially organized blood clot containing

proliferating fibroblasts invading the thrombus. In certain instances there was evidence of recanalization of the thrombus (Fig. 4).

The results of the foregoing experiments are quite significant and shed valuable light on the effect of liquaemin on thrombus formation. It appears that under certain conditions liquaemin is effective in causing the solution or disappearance of a clot especially when administered during the very early stages of its formation. It is of no effect if given during the later stages of clot formation, when it is undergoing organization. It is difficult to explain the mechanism of this action, since it is a well-known physiologic fact that heparin is not a solvent of fibrin. It was, therefore, decided to carry out the following experiments in vitro. A few drops of blood were withdrawn from the ear vein of a normal rabbit, allowed to clot, and the fibrin separated. The fibrin

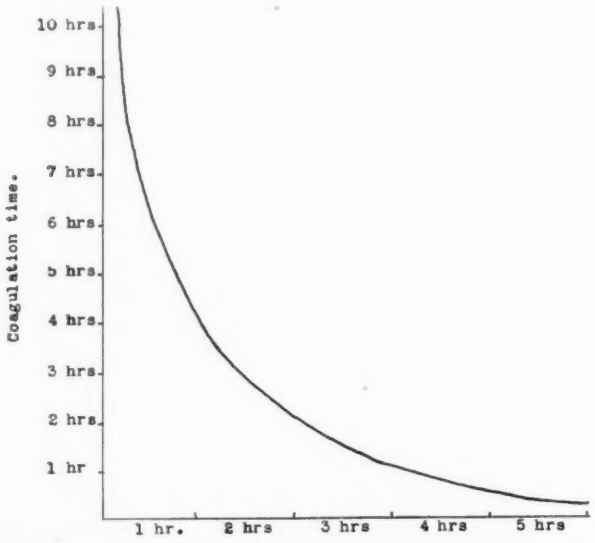


Chart 1.—Time of withdrawal of blood after the injection of liquaemin.

was then mixed thoroughly with various dilutions of liquaemin and incubated at body temperature for several hours. It was found that the fibrin remained unaffected by liquaemin even when the latter was used undiluted. The failure of liquaemin to dissolve fibrin in vitro is in contradiction to the findings noted in vivo, and we are at a loss at the present time to explain the difference in results obtained. One may speculate by saying that some other yet unexplained factor, or factors, may come into play in vivo and may not be apparent in vitro experiments, but this is as far as one can go with the present state of our knowledge concerning the mechanism of liquaemin action.

## COMMENT

Conclusive experimental and clinical evidence has accumulated, especially in recent years, to demonstrate the fact that injury to the endo-

thelium of a blood vessel will produce a local thrombus in a large number of instances, and that the formation of this clot is enhanced if the circulation at the site of trauma is simultaneously retarded. Also, the experimental facts cited in this communication demonstrate quite clearly that liquaemin through its prolonged effects on the coagulation of the blood will prevent the formation of such a thrombus if administered to the animal before injuring the blood vessel. It is particularly effective in preventing clot formation if administered both before and after injuring the vessel wall. Of particular interest is the fact that the injection of a single dose of the anticoagulant was sufficient to prevent the formation of a thrombus in a relatively large percentage of the traumatized veins. It will be recalled that Murray and his associates were not successful in preventing the formation of a mechanically produced thrombus in the dog when a single dose of heparin was administered to the animal before injuring the vessel. According to their experiments heparin proved effective only in cases where the solution was administered continuously for some time following the mechanical injury to the vein. An attempt was made to explain these differences in results by assuming that the liquaemin used in the present series of experiments was a more potent anticoagulant than the heparin which they have used. It was also felt that the different types of animals used in the individual series of experiments played a determining role. Such explanations are entirely hypothetical and therefore of little practical significance. While it is conceivable that such factors may exist, no sufficient evidence can be presented at the present time to prove these facts.

Of added interest is the fact that liquaemin is effective in certain instances in causing the solution or disappearance of a clot if given during the early phases of its formation, namely, the second or third day, but it is of no effect if given late after the clot has reached the stage of organization. Here again, it is very difficult to explain the mechanism involved in such a process, since it is a well-established fact that heparin has no effect on fibrin solution. This was substantiated in our in vitro experiments where the addition of liquaemin to fibrin freshly obtained from the rabbit's blood had no effect. It is debatable whether other factors come into play in vivo which are not apparent in vitro and which may explain the solution or disappearance of the clot when liquaemin is used.

The foregoing evidence has a definite clinical application and the importance of these findings is quite obvious. The most dreaded complication of surgery, particularly in the aged and debilitated individual, is the formation of a thrombus. That this picture is not overdrawn is shown by the mortality figures of all the hospitals of the country, and the measures available at the present time to counteract such a catastrophe, to our knowledge, are still inadequate. This is, therefore, a promising development and if by this means it will be possible to pre-

vent the formation of a clot, the prognosis will be materially improved. Whereas this can be determined only by further experience, the anticoagulant certainly merits a trial in all such cases where thrombus formation is prone to occur. The problem is already receiving increasing thought, as is shown by the ever growing investigations upon the subject. Murray has undoubtedly made one of the most important advances in the therapeutic consideration of heparin with the introduction of the anticoagulant in surgery of the vascular system.

It also appears from the results of the experiments cited above, that liquaemin has a definite effect on formed clot, but only when the latter is still in the early stages of its formation. Should this prove to be the fact in the human being, it will unquestionably have a wide clinical application. It will be of particular use in diseases in which there is extensive thrombus formation or expectation of it, such as in pulmonary, coronary, pelvic, and other vessels, and in which there may be great danger to life through embolism as well.

## SUMMARY AND CONCLUSIONS

1. An experimental method of producing a thrombus in a vein by injuring its endothelial lining and slowing the local circulation has been presented.

2. Liquaemin has been shown to be a powerful anticoagulant of the rabbit's blood even when administered in small single doses.

3. The administration of liquaemin before injuring the vein and the formation of a thrombus will prevent the subsequent development of a local intravascular clot. It was found unnecessary to administer the anticoagulant continuously in order to obtain the desired effects of the drug.

4. In a certain number of cases, liquaemin proved effective in causing the solution or disappearance of a thrombus but only when given during the early stages of clot formation. It was of no effect when given late after the clot had already organized.

5. The clinical application of these findings has been briefly discussed.

We wish to express our indebtedness to the American Medical Association for their grant which enabled us to carry out these experiments.

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# INTRAVENOUS CLOTTING AND ITS SEQUELAE

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INTRAVENOUS clotting is feared by all surgeons, not because of the venous thrombosis per se, but because of the potential sequelae. The complications of venous thrombosis vary considerably in their manifestations and in their prognosis. Nothing could be more tragic than the sudden instantaneous fatality from massive pulmonary embolism following an apparently normal convalescence from a clean operative procedure, and the persistence of postphlebitic edema following phlegmasia alba dolens is indeed disabling.

It is not within the scope of this presentation to discuss the etiologic factors in intravenous clotting. These have been covered in detail in previous publications.[1-4] It is of importance, however, in considering intravenous thrombosis to differentiate between the two types as previously emphasized by us,[1, 3, 4] not only because of difference in the mechanism of development but also because of the variation in prognosis and therapy. Whereas most postoperative and postpuerperal intravenous thromboses are the result of inflammation of the vein wall with consequent clotting of the blood, i.e., thrombophlebitis, there are many cases of venous thrombosis in which there is no associated inflammation of the vein wall, that is, phlebothrombosis. Thrombophlebitis is accompanied by definite symptoms, pain, fever, and swelling and because of this the diagnosis is easy but the diagnosis in phlebothrombosis is less evident because the symptoms are either very mild or entirely absent. As previously emphasized by us, the latter condition is not associated with an inflammation of the vein wall and for this reason the clot is not firmly attached. There is likely to be little or no pain, no swelling, and no fever. Of greatest importance is the elevation of the pulse rate out of proportion to anything else and frequently a sense of impending disaster by the patient.

The prognoses in the two types of intravenous clotting vary considerably. In thrombophlebitis, because the coagulum is the result of changes in the vascular endothelium caused by the associated inflammation, the clot is firmly attached to the vein wall, and is either a white or

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a mixed thrombus. It is for this reason that the clot seldom becomes detached and it is not likely to develop into an embolus. The only conditions under which embolism can occur in thrombophlebitis are in those cases in which a red or coagulation thrombus proximal to the white or mixed thrombus, or in those relatively rare cases of suppurative thrombophlebitis in which liquefaction of the clot by the infection may occur with separation of infected emboli. Although patients with thrombophlebitis seldom develop emboli and therefore do not succumb to massive pulmonary embolism, they live to develop postphlebitic sequelae. On the other hand, patients with phlebothrombosis in whom there is no associated inflammation of the vein wall and in whom the intravenous clotting is the result of changes in the fluid and solid constituents of the blood together with circulatory retardation are potential fatalities because the clot which is a coagulation thrombus is not attached to the vein wall and is easily loosened, resulting in pulmonary embolism, either a massive one or a smaller one resulting in pulmonary infarction.

The treatment of most of the intravenous clottings and their sequelae consists principally in preventing the thrombosis, and although it is not the purpose of this presentation to discuss the causes of intravenous clotting it must be emphasized that any trauma, whether it is the result of an infection, an invasion by malignant disease, operative, accidental, or puerperal injury, produces changes in the constituents of the blood which predispose to clotting. If in addition to these changes there is circulatory retardation, which is likely to occur in the lower extremity, intravenous clotting is favored. By minimizing the operative trauma, the tendency toward thrombosis can be decreased. Of greatest importance, however, is the prevention of circulatory retardation in patients who have had tissue trauma with resulting blood changes. These frequently consist of avoiding vasospastic influences such as exposure to cold, and smoking; the correction of cardiovascular disorders; and the prevention of stasis within the vascular system by overcoming abdominal distention, by encouraging deep breathing, and by mobilization of the extremities.

As mentioned previously, it is not the thrombus per se which is of interest to the physician and patient but rather its potential sequelae. In phlebothrombosis, embolism and its complications are the important sequelae. Embolism may result in sudden fatality because of massive plugging of the pulmonary arteries which has been demonstrated by Gibbon[5] to occur when the lumen of the pulmonary vessel is decreased to 15 per cent or less of its original size. In most cases of pulmonary embolism the attack is not fatal, and according to Barker, Nygaard, Walters, and Priestley[6] only 24 per cent of the cases of pulmonary embolism are fatal with the first attack. In the other cases of pulmonary embolism, the clot is smaller, producing obstruction in the smaller

branches of the pulmonary artery. This results in infarction of the lung, which is of importance not only because of its associated pneumonitis but also because it is a warning that the patient has a focus from which emboli can originate and produce a fatal embolism. According to Zink,[7] 70 per cent of patients with fatal pulmonary embolism have had an antecedent infarction. As emphasized by Barker, Nygaard, Walters, and Priestley,[6] patients with multiple episodes of pulmonary embolism terminate in a fatality in about 60 per cent. They also found that in all cases of fatal embolism, the final attack was preceded by one or more nonfatal attacks in 36 per cent. Of great importance in nonfatal pulmonary infarction is the necessity of preventing further embolism and particularly massive pulmonary embolism. In addition to this, although of less importance, is the possibility of pneumonitis occurring in the lung as the result of the disturbance in blood supply and superimposed infection of the pulmonary parenchyma. Another possible complication of embolism which occurs relatively infrequently is pulmonary arterial fibrosis which has been emphasized by Belt.[8] He believes that this is likely to follow recurrent, nonfatal embolism resulting in subsequent pulmonary thrombosis and fibrosis.

The sequelae of thrombophlebitis must be divided into two types, those which follow the nonsuppurative variety and are by far the most common and those which follow the suppurative lesions. Those which follow the nonsuppurative type of thrombophlebitis are postphlebitic edema, postphlebitic streptococcic infection, and postphlebitic ulceration. Following the suppurative variety, embolism is the most important sequel. This may result in septic infarction with the development of pneumonitis or pulmonary abscess and even sepsis.

As mentioned previously, the treatment of intravenous thrombosis is primarily that of prophylaxis. If, however, phlebothrombosis or thrombophlebitis occur, their sequelae also can be prevented by prophylactic management, which is without doubt the best form of therapy. The prophylactic therapy for embolism in phlebothrombosis consists of the early detection of the intravenous lesion and the institution of measures to prevent the detachment of the clot with resulting embolism. As mentioned before, the clinical manifestations of phlebothrombosis are not marked, and it is for this reason that the condition is likely to be overlooked unless one considers the possibility of its existence. Too frequently a patient who has had a relatively simple operative procedure and who is apparently convalescing nicely develops a fatal pulmonary embolism upon first getting out of bed. This can usually be obviated. In any individual in whom intravenous thrombosis might occur, particularly if there has been extensive tissue trauma, and in an individual in whom circulatory retardation is likely, such as elderly persons with impaired cardiovascular activity, the possibility of phlebo-

thrombosis must be considered. Whereas they do not present the typical picture seen in thrombophlebitis, such as swelling of and pain in the extremity, and fever, they frequently have a tachycardia which is out of proportion to all other findings. This should immediately make one suspicious of the possibility of a phlebothrombosis. This together with an associated increase in erythrocytic sedimentation rate is of diagnostic importance. Of diagnostic importance also is the detection of tenderness along the course of possibly involved veins. In elderly individuals in whom thrombosis is likely, careful routine examinations of the lower extremities are essential. Since many of the thrombi begin in the plantar veins of the soles of the feet, tenderness on compression of the foot is of diagnostic significance. Neumann[9] found that the plantar veins were involved in 71 per cent of cases of intravenous clotting and that solitary plantar vein thrombosis occurred in 12 per cent. Tenderness on forceful compression of the calf muscles and pain in the calf and popliteal space when the foot is forcefully dorsiflexed as suggested by Homans[10] is indicative of thrombosis of the deep veins of the calf. Neumann[9] found the calf veins involved in 87 per cent of cases with intravenous thrombosis and the thromboses were limited to these veins in 29 per cent. Rössle,[11] in post-mortem studies, found that 25 per cent of all patients had calf vein thromboses. One should palpate along the course of the femoral vessels also to determine the possible existence of thromboses in them. Careful measurements of the circumference of the lower extremities are of importance in the early detection of intravenous clotting, and enlargements of one or both extremities is suggestive of beginning thrombosis.

If any of these symptoms and signs are present one must suspect an intravenous clot, and phlebography is imperative. This will not only demonstrate the presence or absence of a clot but will also give its location. Phlebography was advocated by dos Santos[12] and Bauer,[13] and has been popularized in this country by Welch and his associates.[14] It is a procedure which is virtually without danger and should be employed in all suspected cases of phlebothrombosis. Phlebography as practiced in our clinic[15] is briefly as follows: With the patient in the supine position on the roentgenographic table a tourniquet is placed around the upper part of the thigh just below the fossa ovalis and applied tightly enough to compress the superficial veins. A 7 by 14 cassette is placed beneath the leg and lower part of the thigh and a 17 by 14 cassette placed in tandem above this extending up to the pelvis. The lower cassette is placed so that it extends above the knee to include the popliteal vein on this film. The extremity is rotated somewhat medially in order to separate the shadows of the tibia and fibula. Into a superficial vein of the foot are injected 25 c.c. of a 35 per cent diodrast solution at a rate of about 1 c.c. per second. Approximately 25 to 30 seconds after the completion of the injection the exposure is made in order to bring out

soft tissue detail. It is desirable to have the roentgenographic tube arranged in such a way that both the lower and upper films can be exposed at the same time. This is possible only if the tube film distance is at least six feet. If it is not possible to have the tube six feet above the table, visualization of the leg and popliteal vessels should be done first and later a similar visualization of the veins of the thigh obtained. Before attempting phlebography it is desirable that one familiarize himself with a normal phlebogram because only by contrasting the findings in a given case with those found normally can one determine whether an intravenous clot is present and accurately locate a thrombus visualized as a defect in the normal venous system.

If phlebography demonstrates the presence of an intravenous clot it is imperative that steps be taken either to remove the clot or to prevent its migration into the systemic circulation. Depending upon the location of the clot the vein should be exposed and either tied above the clot or the vein opened and the clot removed. If the thrombus is located in the superficial vein it is relatively simple to ligate the involved vein above the thrombus. If, however, the deep venous system is involved, in which case the thrombus frequently extends into the iliac, one may either expose the iliac vein and ligate above the thrombus or preferably open the femoral vein at its junction with the saphenous and remove the thrombus by means of suction. This can be done if need be in the patient's room, but is best done in the operating room. Under local analgesia, the femoral vein and its tributaries in its upper portion are exposed. Care is taken not to manipulate the veins any more than is absolutely necessary because a thrombus which frequently is difficult to detect before the vein is opened can be dislodged easily. After careful dissection a ligature is loosely placed around the profunda vein, another around the femoral below this, and another above the saphenous vein is doubly clamped close to the femoral and divided. The distal end is ligated. With the head of the patient somewhat elevated in order to increase the venous pressure, the clamp on the proximal end of the saphenous vein is removed and the edges of the open vein caught with mosquito forceps. If no bleeding occurs it is evident that there is a thrombus in the femoral vein. A suction tip is introduced into the lumen of the femoral vein and directed cephalad. By means of gentle suction the contained thrombus is removed. Complete evacuation of the clot proximal to the opening in the vein is indicated by free retrograde flow of blood from the proximal end of the vein. The ligatures which previously had been placed around the femoral are tied. By this procedure detachment of the thrombus is prevented and embolism is obviated.

Although prophylactic therapy of embolism in phlebothrombosis is the ideal method of treatment, there are many patients who are seen for the first time after embolism has occurred. The active therapy of

a patient with pulmonary embolism depends to a large extent upon the type of embolism. If there has been a massive pulmonary embolism resulting in obliteration of a considerable portion of the pulmonary artery, energetic radical procedures are necessary. Because there is probably an associated spasm of the remaining pulmonary vessels, measures to relieve the spasm are of great importance. As emphasized by Jesser and deTakats,[16] the intravenous administration of papaverine and atropine because of their antispasmodic effect are beneficial. Novocain block of the cervicodorsal sympathetic ganglia will relieve many of these patients and save lives. Because their oxygenation is greatly impaired it is imperative that these patients receive inhalations of oxygen in high concentrations as it minimizes respiratory and cardiac efforts.

Although embolectomy as originally suggested by Trendelenburg was considered quite popular one and one-half decades ago, it is now relatively infrequently used. The number of patients who have been saved by this heroic procedure is so small that it offers relatively little in the treatment of pulmonary embolism. Certainly one is most justified in watching the patient who has had one or more nonfatal emboli until fatal embolism occurs as has been suggested by some of the continental workers. It is far better to prevent pulmonary embolism by the prophylactic measures outlined above.

In the patient who has had a nonfatal pulmonary embolism with infarction it is imperative to control the pneumonitis which may result. Fortunately, this is not much of a problem today with the use of the sulfonamides. Oxygen administration is desirable in pneumonitis for the same reason that it is valuable in massive pulmonary embolism.

In thrombophlebitis in which, as mentioned previously, there are marked clinical manifestations and in which the diagnosis is not difficult to make, prevention of sequelae is important. In the nonsuppurative variety postphlebitic edema, postphlebitic streptococcic infection, and postphlebitic ulceration are the most disabling sequelae. As we[1-4] have demonstrated repeatedly, the prophylactic treatment of postphlebitic edema consists of the production of vasodilatation during the acute phase of thrombophlebitis by repeated procaine anesthetization of the regional sympathetic ganglia. Whereas previously the convalescence in these cases was prolonged from six to eight weeks and the postphlebitic edema persisted for months or even years, these patients now can be perfectly well within a week or ten days by the use of this conservative therapy. Daily procaine injections of the sympathetic ganglia should be done as long as the patient has fever because it is our opinion that the persistence of fever is an indication of the persistence of the thrombophlebitic process which results in the spasm of the arterioles, which in turn is responsible for the edema. From a biological standpoint it is of interest that whereas in thrombophlebitis the lesion is

limited to the venous system, the symptoms are almost entirely those referable to the arteriolar system, the arteriolar contraction being the result of vasospastic impulses originating in the thrombophlebitic segment.

In addition to the vasodilatation secured by the procaine block of the regional sympathetic ganglia, it is important that the extremity is wrapped with compression bandages. This is best accomplished by the application of an Ace No. 8 bandage from the toes up to the upper limit of the swelling. Immediately after the application of the compression bandage, the extremity should be mobilized. Instead of having the patient keep his legs perfectly quiet as was previously done, he should be made to move them frequently and preferably against a resistance. Active flexion of the foot against a resistance ten to fifteen times every hour is of great value in these cases.

Unfortunately, there are many cases in which active therapy was not used during the acute thrombophlebitis so that postphlebitic edema develops. There are few lesions which are more disabling than the edema which follows an antecedent phlebitis many years previously. It is for this reason that it is desirable that something be done for these chronically disabled patients who have not been adequately treated during the period of their acute phlebitis. Whereas it was our original contention that the chronic persistent postphlebitic edema would be benefited little or none by vasodilatation because it was difficult to understand how vasospasm could play a role in such a lesion, we are now equally as convinced that most if not all chronic postphlebitic edemas can be relieved by the institution of vasodilatation. The results although less dramatic than in acute thrombophlebitis are equally as acceptable to the patient because the patient with the acute thrombophlebitis who is well within a week or ten days cannot appreciate to the same degree the results obtained as can the patient who has had a swollen painful extremity for many years and who is similarly relieved although it may take a longer period of time. It is relatively easy to determine whether or not vasoconstriction is a factor in the production of the symptoms by determining the effect of the vasodilatation on the edema. The patient is instructed to walk a given distance, usually about a mile at a normal rate of speed. Following this, careful measurements of the involved extremity are made. The circumference of the thigh at two levels, the circumference of the knee, and the circumference of the leg at two levels are determined. Procaine block of the homolateral sympathetic ganglia is done and after approximately 20 to 30 minutes have elapsed to permit the block to become complete the patient again walks the same distance at approximately the same rate of speed. Following the completion of this tour, measurements of the extremity at the same levels are made. If there is a decrease in the size of the extremity following the

anesthetization it is evident that vasoconstriction plays a role in the production of the edema and it is logical that vasodilatation will have a beneficial effect. In all cases of postphlebitic edema, unless there is some definite indication for active radical therapy, conservative measures should be used. These consist of reflex vasodilatation by the application of heat to an uninvolved portion of the body as originally suggested by Lewis and Pickering,[17] and Landis, and Gibbon.[18-20] This can be accomplished either by immersing an uninvolved extremity, such as the arm, in hot water two to three times a day for about 30 minutes, or by the application of a hot-water bag or heating pad to the abdomen after retiring at night. Repeated procaine blocks of the lumbar sympathetic ganglia are of value and will frequently apparently break the vicious cycle and permit prompt resolution. It is imperative that these patients avoid vasoconstricting measures such as chilling and smoking. Patients should be instructed to avoid getting chilled at all times. They should wear bed socks during the night and should protect their extremities and the rest of their body during cool weather. It is also essential that they refrain from smoking because of the vasospastic influence that it exerts. Of great importance in the conservative treatment of thrombophlebitis is the compression of the involved extremity because it is our firm belief that no individual should be allowed to have edema. This is best accomplished by wrapping the extremity with Ace No. 8 bandages, the wrapping extending from the toes to above the area of swelling. The bandage should be applied in bed before the patient arises in the morning and removed upon retiring at night. The administration of relatively large doses of vitamin $B_1$ is of value apparently because it favors oxidation in the tissues, which in turn decreases the permeability of the capillary endothelium.

In the severe case and in some individuals for economic reasons, such as the laborer who is incapacitated because of his postphlebitic edema, radical procedures to produce vasodilatation are essential. In these cases resection of the regional sympathetic ganglia to produce a permanent vasodilatation is desirable. Whereas sympathetic ganglionectomy may seem at first thought a very radical procedure, it is undoubtedly the best type of therapy in the individual whose livelihood is jeopardized by disability resulting from persistent postphlebitic edema. By performing the operation through a muscle-splitting approach which we have employed for years it is possible for the patient to be out of bed within three days and be discharged from the hospital on the fifth postoperative day.[21]

Relatively rarely in patients who have had a postphlebitic edema over a long period of time, there may occur recurrent streptococcic infections which are of great importance not only because of the disability which the infection intself produces but also because of the likelihood of

fibrosis resulting from the infection. This condition consists of recurrent attacks of chills and fever associated with burning, itching, pain, and redness of the extremity. These result from the flare-up of a dormant streptococcic infection of the skin of the extremity or as the result of sensitivity of the skin to an acute streptococcic infection elsewhere in the body such as the throat. There is deposited in the skin and subcutaneous tissues a considerable amount of fibrous tissue resulting in a true elephantiasis and characteristically the condition becomes worse with each attack. This is best treated prophylactically by using the same measures used for the prevention of postphlebitic edema. The active therapy of this recurrent erysipeloid condition consists first of producing vasodilatation by the same measures which are used in postphlebitic edema. In addition, compression and active mobilization of the extremity are essential and sulfonamide therapy is necessary. Whereas Ochsner, Longacre, and Murray[22] reported that sulfonamides were of little value in these cases, we have subsequently found that the administration of sulfadiazine in large doses for a week out of each month will usually control and prevent recurrences. As advocated by Trout,[23] the administration of relatively large doses of sulfanilamide not only during the attack but also at monthly intervals for a year is essential. It is the rule in our clinic that these patients receive from 60 to 90 gr. of sulfadiazine a day for a week out of each month. In this way the dormant microorganisms in the tissues or other parts of the body can be eliminated. In a case in which the condition has been present for a long time it is occasionally necessary to resort to a radical procedure such as a modified Kondoleon operation because only by such therapy can the excessive subcutaneous fibrous tissue which is responsible for the persistence of the edema be removed.

Another infrequent complication of thrombophlebitis is postphlebitic ulceration. Here also the treatment consists primarily of prophylaxis and by preventing the thrombophlebitis and the subsequent edema, postphlebitic ulcerations can be prevented. The active therapy consists of the institution of vasodilatation, the use of compression bandages, and mobilization. Sulfonamide therapy is very helpful because of the frequent presence of streptococci in the ulcer and the surrounding tissues. Because these cases also have varicosities of the superficial veins and the communicating veins between the superficial and deep systems, these must be corrected before the ulcer will heal. Generally the usually successful methods of therapy of varicosities will fail because of the presence of one or more large communicating veins in the base of the ulcer in which the valves are incompetent, permitting retrograde flow from the deep to the superficial systems. In order to accomplish a cure it is necessary to ligate these veins, and it is usually desirable to excise the ulcer and surrounding scar tissue and cover the defect with skin graft.

Suppurative thrombophlebitis is frequently associated with puerperal sepsis and occasionally in other infections involving an extremity. The danger in such a case is the breaking off of infected emboli with the production of secondary septic processes at the site of lodgment of the embolus and also the possibility of a blood stream infection. Here again prophylaxis is of greatest importance. Ligation of the vein proximal to the site of the thrombus is imperative. Occasionally, excision of the involved vein is the preferable procedure as is frequently the case in thrombophlebitis involving the superficial veins of the extremity. These same procedures are used as active therapy once the condition has occurred. The site of election for the vein ligation depends upon the veins involved and the extent of the process. In many cases of pelvic infections associated with septic puerperal infections because of the widespread involvement, it is necessary to ligate the vena cava. Conrad Collins, of our department of gynecology, has ligated the vena cava in twelve cases of suppurative pelvic thrombophlebitis. This procedure has also been done on our service in three cases of suppurative thrombophlebitis originating in the pelvic veins, and it is astounding to see the dramatic results which can be obtained in these cases following the ligation of the vena cava, which mechanically prevents the dissemination of infected emboli.

Although ligation of the vena cava may seem a very radical procedure and far too extensive to be justified, our results demonstrate that not only is the operation lifesaving but also that it is attended with little risk and few if any sequelae. Nothing is more dramatic than the complete cessation of all chills and the prompt subsidence of fever in a patient who previously had recurrent chills and fever and was critically ill. The results in such a case are due to the prevention of dissemination of the infected emboli which if allowed to continue would almost invariably result in sepsis and death.

## SUMMARY

Intravenous clotting per se is of little significance but its sequelae are of great importance.

In the consideration of the sequelae of intravenous thrombosis, it is necessary to differentiate between the two types of intravenous clotting, i.e., phlebothrombosis and thrombophlebitis. The thrombus in the former is loosely attached and is likely to become detached resulting in embolism. Embolism in thrombophlebitis occurs infrequently because the thrombus is firmly attached to the vein wall. Only when a coagulation thrombus, which is a red clot and not attached, forms proximal to the thrombophlebitic area, or when suppuration occurs in the thrombophlebitic processes, with liquefaction of the clot, does embolism occur in thrombophlebitis.

The sequelae of nonsuppurative thrombophlebitis are postphlebitic edema, postphlebitic streptococcic infection, and postphlebitic ulceration. All these are best treated prophylactically, i.e., the institution of vasodilatation during the acute stage of thrombophlebitis. Vasodilatation is of great benefit even after the sequelae have developed. Postphlebitic streptococcic infections, in addition, require the administration of sulfonamides at regular intervals for a year or more.

In postphlebitic ulceration the associated varicosities of the superficial and communicating veins must be corrected.

The treatment of embolism is also that of prophylaxis. In phlebothrombosis early detection of the thrombus by phlebography and either the removal of the clot or the ligation of the vein above the clot are imperative. In suppurative thrombophlebitis, ligation of the involved vein above the thrombophlebitic segment or the extirpation of the involved vein and thrombus is necessary to prevent pneumonitis, sepsis, and death.

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# ONE-STAGE PERINEO-ABDOMINAL OPERATION FOR CANCER OF THE RECTUM

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THE Kraske operation for cancer of the rectum, which came into use about fifty years ago, was probably the most serious procedure that surgery imposed upon a patient at that time. At least, it was one of the most tedious and difficult, if not the most hazardous of operations. This was a very courageous attempt to eradicate cancer of the rectum and the areas to which it spread, and in truth it was a far step in the satisfactory removal of cancer in this region. Properly done, the entire rectum and a large amount of the sigmoid could be removed, with the gland-bearing tissues as well. It necessitated a perineal colostomy which was more acceptable to the patient, and for a long time it seemed to be as satisfactory as an operation could be in this part of the body for this disease. Still the mortality was high, and subsequent studies of the spread of the disease showed that cancerous tissue was left which might be removed with a still more extensive operation, provided the abdomen was opened and an abdominal colostomy was resorted to.

At the present time the maximum attainment in surgical procedures for eradication of cancer of the rectum is that based upon the operation which now carries the name of Miles radical procedure, which, as is well known, contemplates the complete removal of the anus, rectum, and lower part of the sigmoid flexure with gland bearing tissue about these parts of the large bowel. This procedure has been popularized by a great many capable surgeons. Rankin, Jones, Bartlett, and others have made some modifications of the Miles procedure but generally the operation is the same, and the abdomino-perineal procedure in the sequence mentioned is used by a great majority of surgeons at this time. We practiced this operation for some time but found it technically quite difficult on any occasions, particularly in the male patient whose pelvis is very deep and narrow. Also, the difficulty was increased if there was distention of the bowel, and if the anesthetic was not perfect.

Since 1930, we have utilized the reverse sequence in the operation, that is, the perineo-abdominal sequence, almost exclusively because we have found this method so very much easier to perform and our patients are in much better condition after the operation than previously experienced. We have done the operation on forty-six consecutive patients

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for cancer of the rectum. Of these patients, two have died following operation, both early in our experience. One patient apparently died of delayed shock as autopsy revealed no cause for death although generally he was a very favorable risk. The second patient, a woman, had an intestinal obstruction due to a herniation of a loop of bowel through the perineo-peritoneal suture line, which should not have occurred, and should have been recognized early enough to prevent death. No patient other than these two was in a grave condition at any time and we have not had a death in the last thirty-nine consecutive cases. We are so impressed with the advantages of the operation that we are here giving a description of the procedure and also a discussion of the advantages and disadvantages of it.

## METHOD OF PROCEDURE

1. A purgative is given forty-eight hours before operation. We do not emphasize a long preoperative preparation of the patient as is so generally stressed by many writers. If the colon is very empty we see very little reason for endeavoring to make it completely empty or clean from the standpoint of number of bacteria, by days of fasting and repeated purgation. An enema is given the night before the operation.

2. An indwelling Levin tube is passed in the stomach and gastric suction started before the anesthesia begins. This gastric suction is maintained for a period of three to four days following operation, eliminating all danger of postoperative ileus and distention.

3. The patient is placed on the operating table in an extreme lithotomy position (Fig. 1). We formerly did the perineal portion of the operation with the patient lying on his face over the table with the buttock elevated, which we thought quite satisfactory, but there was some confusion when the patient had to be turned over on his back for the abdominal portion of the operation. For some time we have used the lithotomy position and find it an advantage in that the orientation of the anatomy is more satisfactory and the confusion and trouble of turning the patient over for the second part of the operation is eliminated. An indwelling catheter is placed in the bladder and the bladder allowed to remain empty during the operation and for one week subsequently. The perineal region is scrubbed thoroughly with soap and water and a good brush, and antiseptics used for perineum, buttock, anus, and scrotum.

4. A yard strip of dry gauze is passed into the rectum (Fig. 1). This serves the purpose of identifying the rectum and facilitating dissection; also it absorbs fluid content should there be fluid in the rectum, reducing the danger of soiling if the bowel is accidently opened. Next, the anus is closed by a double row of purse-string sutures, making the anal closure very secure. The incision is made in the usual way from over the coccyx around the anus; in men the tip of the coccyx is removed.

In women it is not necessary to disturb the coccyx. The rectum is freed in the usual way, the inferior hemorrhoidal vessel being identified and doubly ligated, and the levator muscles cut wide of the rectum (Fig. 2). The fascia propria is identified and incised (Fig. 3), and by blunt dissection with the hand within the fascia, the rectum is freed from the hollow of the sacrum.

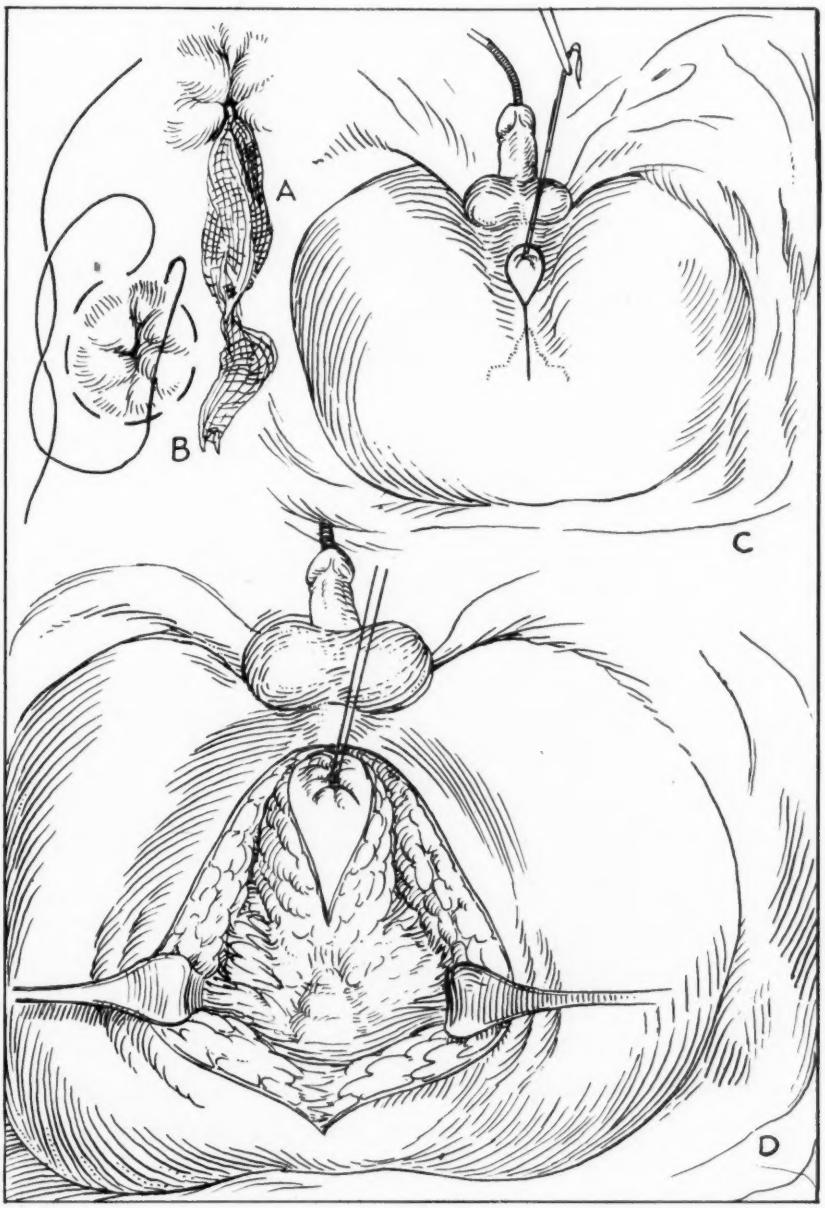


Fig. 1.—Patient in extreme lithotomy or gynecological position; catheter in bladder. (*A*) Yard strip of gauze passed into rectum (*B*). (*C*) Rectum closed with two purse-string stitches. (*D*) Incision made from just above coccyx toward the midline and forward around the anus.

From in front, the separation is made between the urethra and prostate and the rectum in men (Fig. 4). In women the rectum may be dissected from the vagina, but much time and bleeding may be saved

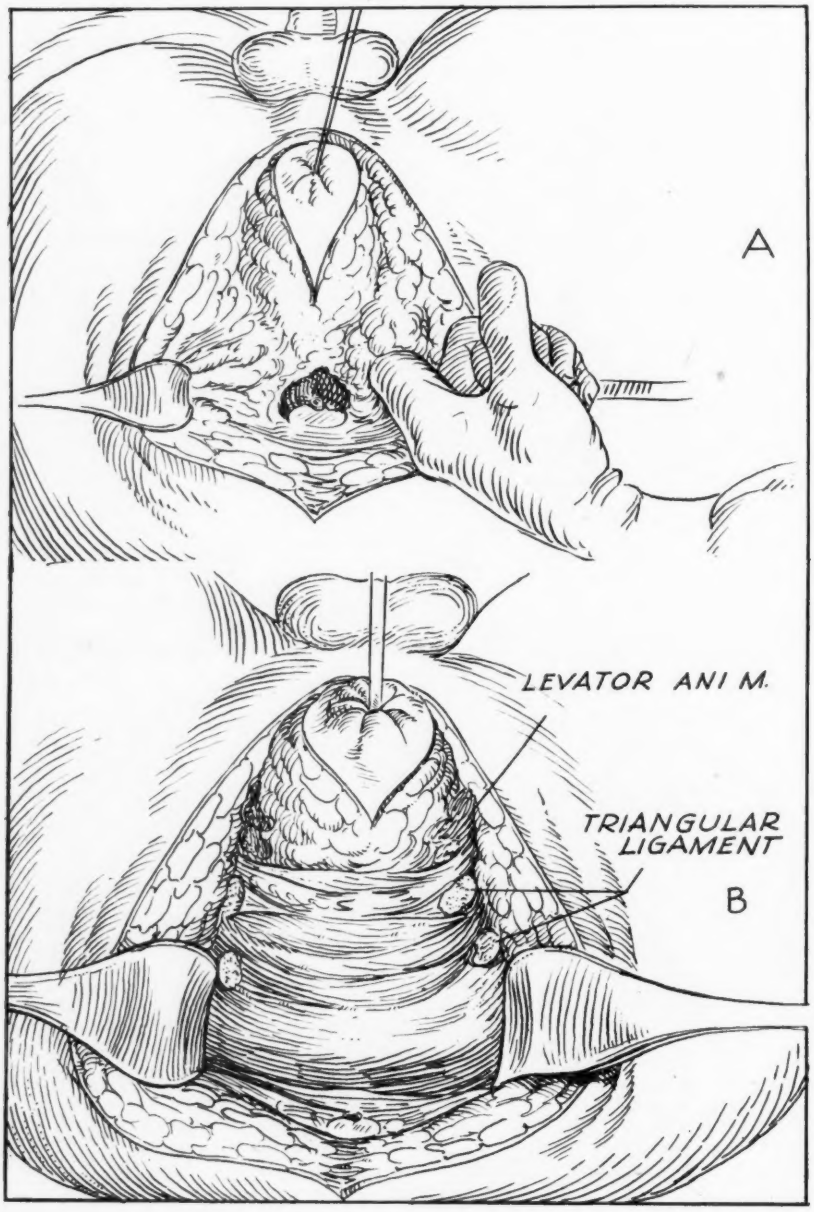


Fig. 2.—(*A*) Coccyx removed in men not in women. Rectum liberated and inferior hemorrhoidal vessels ligated. (*B*) Levator ani muscles cut widely, triangular ligaments of middle hemorrhoidal vessels cut between ligatures.

by removing the posterior wall of the vagina with the rectum. This also has the advantage of lessening the danger of entering the rectum, as well as being a more complete removal of cancer bearing tissue. The

middle hemorrhoidal with the triangular ligaments to the rectum are identified by blunt dissection, ligated, and the rectum freed on each side.

By pushing the peritoneum off the prostate, one opens the peritoneum and enters the peritoneal cavity. This opening is made entirely around

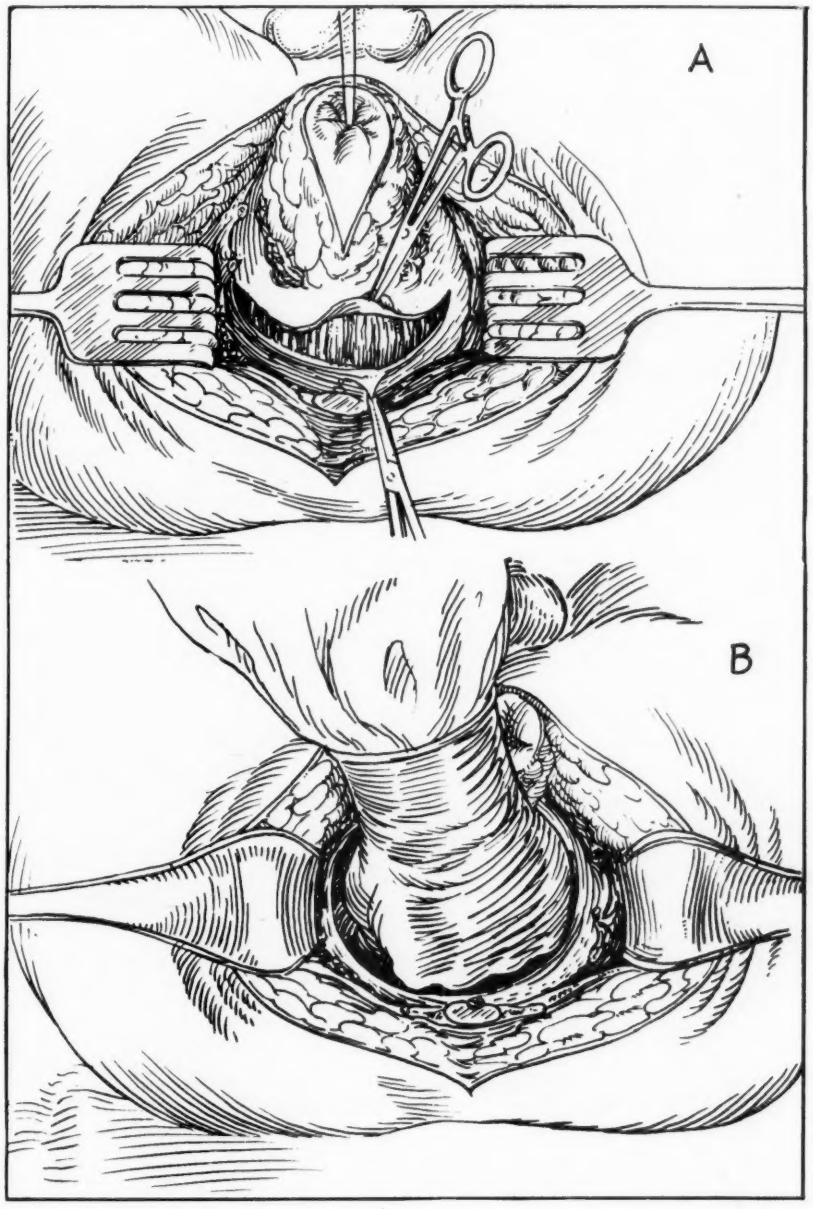


Fig. 3.—(*A*) Fascia propria incised. (*B*) The rectum freed from the hollow of the sacrum by the hand passed within the fascia propria and around the rectum.

the sides and in front of the rectum and the rectum may then be drawn down considerably and the lateral attachments of the peritoneum to the rectum incised up on to the sigmoid.

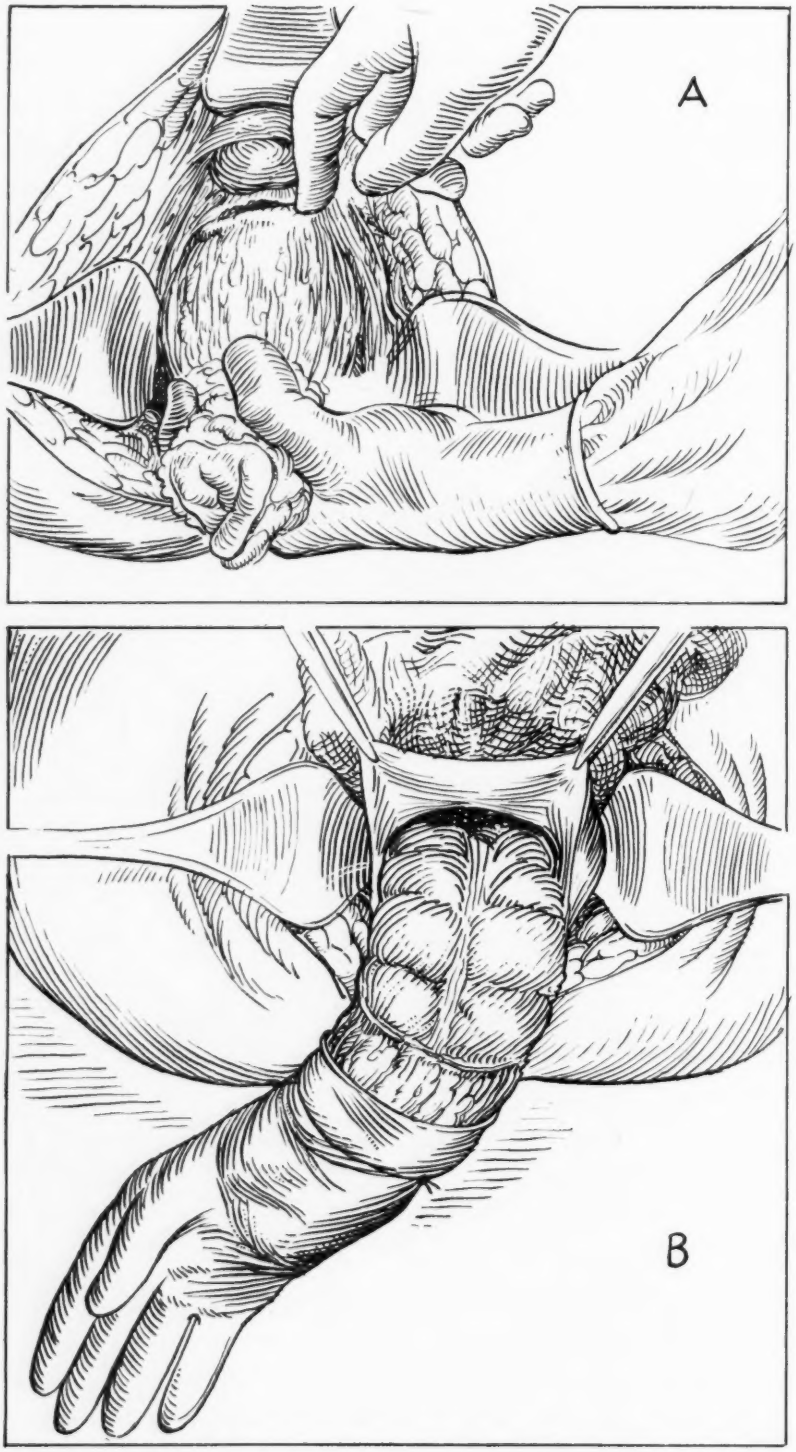


Fig. 4.—(*A*) The rectum is freed from the corpora spongiosum, urethra, and prostate in front. In women the posterior vaginal wall would be removed with the rectum. (*B*) Above the prostate the peritoneal cavity is entered, the peritoneum is incised in front and around the rectosigmoid. The peritoneal attachment to the rectum is incised further up the sigmoid and the rectum and sigmoid further delivered. A sterile glove is now placed over the rectum and tied securely with a strong ligature.

A sterile glove (Fig. 4) is placed over the anal and rectal portion and tied securely, high up, with a strong ligature around the bowel (Fig. 5). Then this portion of the bowel covered with glove is pushed into the peritoneal cavity. The peritoneum, beginning at the bladder, is sutured with a size 0 chromic catgut doubled on a round muscle

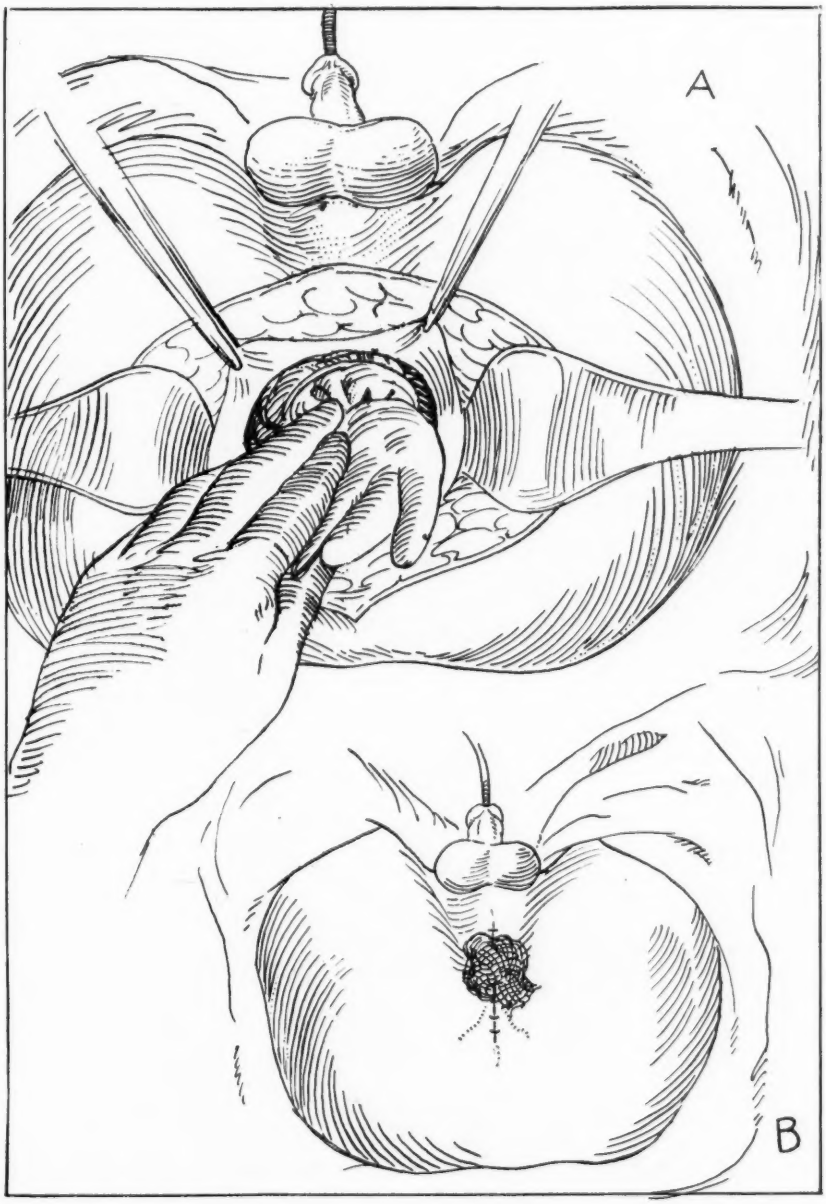


Fig. 5.—(*A*) The rectum covered with a sterile glove is now pushed into the peritoneal cavity. Suture of the peritoneum, beginning near the bladder, is begun with a continuous chromic stitch. The needle and sutures are wrapped on a piece of gauze and pushed in the abdomen. (*B*) A large rubber-covered pack of iodoform gauze is placed in the ischiorectal cavity and the perineal wound closed about it with interrupted skin stitches. Dressings are applied and the patient placed flat on the table prepared for the laparotomy.

needle. The peritoneum is brought together for a short distance and then the needle and suture is wrapped securely around a piece of gauze and pushed into the abdominal cavity. Hemostasis has been controlled as the operation proceeded. The hollow of the sacrum and perineal space from which the rectum has been removed is filled with a large pack of iodoform gauze wrapped with rubber tissue or cellophane. In-

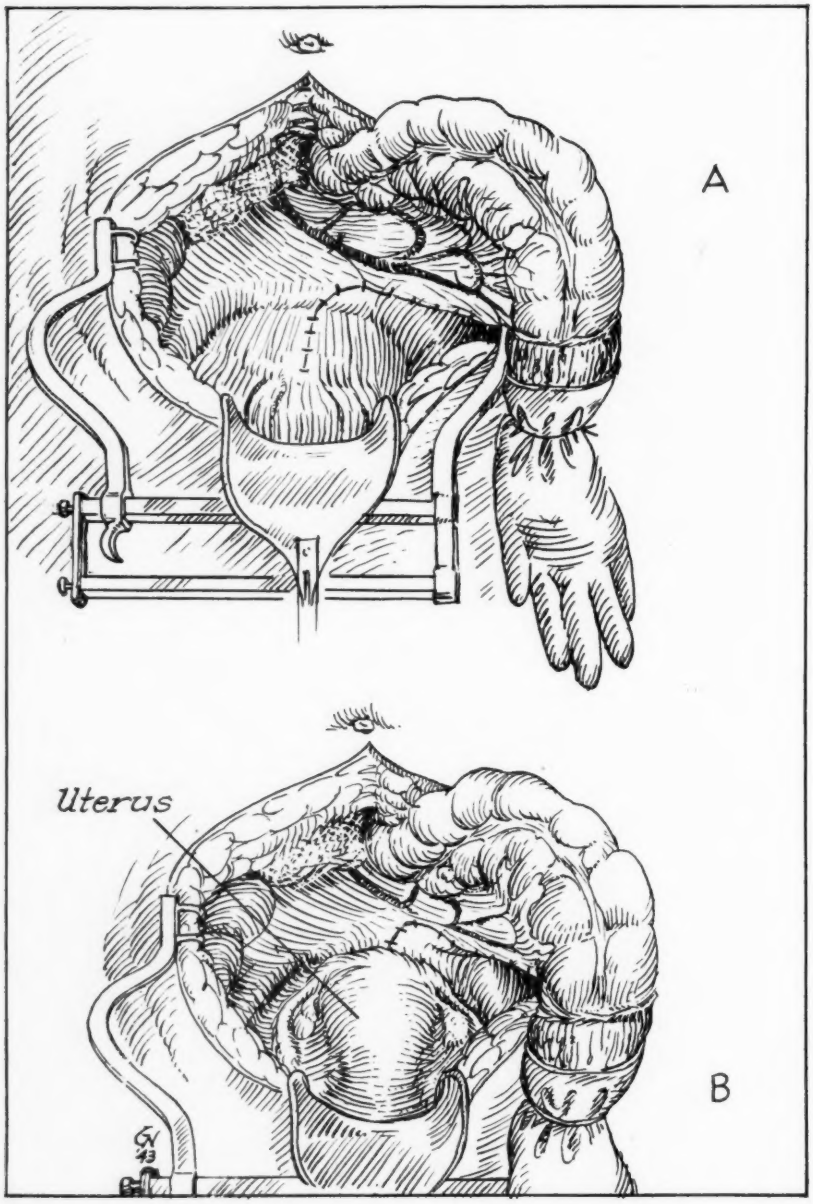


Fig. 6.—(*A*) Midline abdominal incision, glove and rectum recovered and lifted out of abdomen. Inferior hemorrhoid artery ligated and sigmoid flexure freed with gland-bearing tissue. The pelvic peritoneum suture is finished from within the abdomen. (*B*) In women the uterus is tacked back over the line of peritoneal suture.

terrupted stitches close the perineal wound, leaving the drain protruding through the center of the wound. The perineal part of the operation is finished. Dressings are applied. The patient is then placed straight upon the table in the Trendelenburg position and prepared for laparotomy.

After a change of gowns, gloves, and operative tray, a midline incision is made, the small intestines packed out of the way, and a Balfour

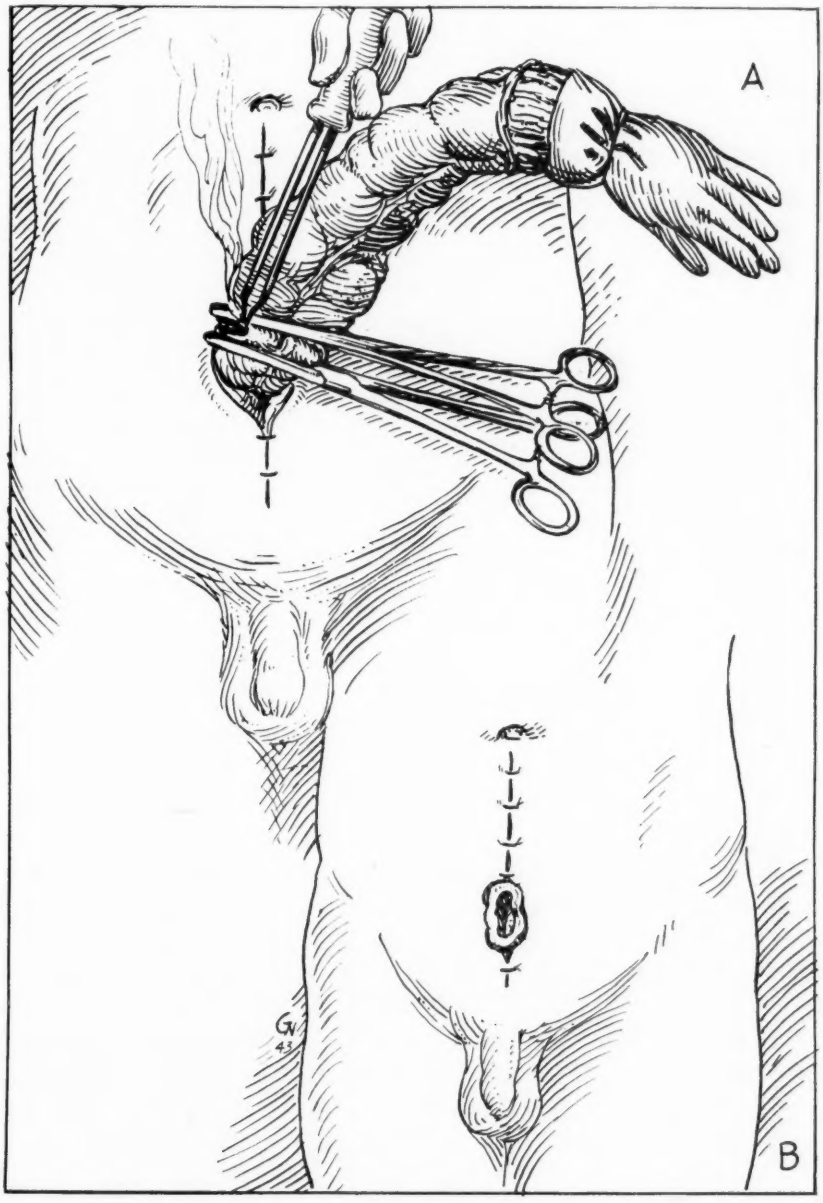


Fig. 7.—(*A*) Abdominal wound is closed about the colon in the middle of the midline incision. Crushing clamps are applied and the bowel is burned across with electric cautery; proximal clamp left on. (*B*) Midline colostomy.

abdominal retractor inserted. The glove-covered rectum is now recovered and brought out of the abdomen (Fig. 6, *A*). The complete liberation of the rectum and sigmoid is completed well on to the sigmoid flexure, with ligation of the superior hemorrhoidal vessels. Then the previously started suturing of the peritoneum is completed. In women the uterus (Fig. 6, *B*) is sutured back over the peritoneal suture line. Since the accident previously mentioned, in which a loop of bowel herniated through this suture line, this precaution has been taken and we think it is worth while.

The colostomy may be made in the left side through a muscle-splitting incision, or it may be left in the center of the midline incision as advocated by Jones and others. At the present time we are inclined to believe that the midline colostomy is less likely to result in hernia. The colon is placed in the proper position for the permanent colostomy, and the abdominal incision is closed about it (Fig. 7, A). When the wound closure is completed, the bowel is doubly clamped distal to the skin and burned across with the electric cautery. Thus the bowel has not been entered at any time until the operation is completed, and then outside of the abdomen. Should a colostomy of the left side be desired, one clamp may be passed through the wound on the left side, and after careful protection with moist gauze the bowel is burned across and the clamp on the proximal end brought out through the side wound. The midline colostomy procedure naturally is less hazardous from the standpoint of infection. The clamp which is on the colon may be left on for thirty-six to forty-eight hours if the intestine is kept free of gas by gastric suction.

We are convinced that the operation is as complete as the Miles procedure.

### CRITICISMS OF THE OPERATION

1. An opportunity is not afforded for examination of the liver and lymph glands for metastasis before operation is completed.

2. The cleansing of the colon before operation is difficult without a previous colostomy.

3. Troublesome ileus may occur following the operation because the colostomy has not developed proper function with a previous colostomy before the removal of a large amount of bowel.

### DEFENSE OF CRITICISMS

1. In answer to the first of these criticisms it should be said that liver metastasis is not contraindicated to resection of the rectum since the patient will live longer and be more comfortable after resection, even though metastasis has occurred in the liver.

2. The perfectly dry and empty bowel is an advantage but with this procedure the bowel is not opened until the operation is finished and with ordinary care the danger of accidentally opening the bowel and

soiling is not present and has not happened in our experience in a single case.

3. If gastric suction is used postoperatively until peristalsis is restored (three to four days), the danger of annoyance from ileus is completely eliminated. Also, the gaseous distention which ordinarily may occur and endanger the abdominal wound and the sutured pelvic peritoneal floor is prevented. Routine gastric suction has eliminated completely the above complications.

ADVANTAGES OF THE OPERATION OVER THE ABDOMINOPERINEAL PROCEDURE

1. It is technically much easier and more rapid of performance. The operation is largely completed before the abdomen is opened. This naturally means a short time in the abdomen with little handling of the intestines, which naturally results in less shock and a more rapid recovery.

2. The chances for infection are greatly reduced because the bowel is not opened until the operation is completed. We have not seen evidence of peritonitis or infection in the wounds of any patient.

3. The surgeon who is not doing a great many resections of the rectum will become more expert with the knowledge gained by a repetition of the same procedure. It is true that the surgeon should have at his command and be able to perform any of the procedures which are usually considered necessary for operations for cancer of the rectum, but we should remember that the operation will be done by many general surgeons who do not have the advantage of a long and extensive experience with rectal excision.

# APPENDICAL ABSCESS

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IT IS generally recognized that, conditions being favorable, the best form of operative treatment for appendical abscess is appendectomy with drainage. It is likewise well known that at times circumstances make removal of the appendix inadvisable if not impossible, and in such cases simple drainage of the abscess is employed. The decision as to whether to remove the appendix or to be content with simple drainage of the abscess must be left to the judgment of the individual surgeon. In this decision he is guided by the general condition of the patient before and during operation and by the relative ease with which the appendectomy may be accomplished. An additional factor of much importance is the subsequent course of the patient as influenced by the type of procedure performed. It is in an attempt to clarify this ultimate prognosis that the present study is undertaken.

A review has been made of all cases of appendical abscess treated at the New York Hospital over the period of ten years, from 1932 to 1942. The cases have been selected on the basis of the condition found at operation. The criteria on which the diagnosis was based were the following: (a) a localized suppurative process was found, (b) a positive culture was obtained from the pus, and (c) a perforated appendix was identified as the origin of the peritoneal infection. In a few cases the appendix itself could not be seen or felt, but in these there was sufficient evidence, on the basis of the location of the abscess and the subsequent course of the patient, to point to the appendix as the offending organ.

According to these criteria no cases were included in the series which had early perforation without evidence of a walling-off process, no case of generalized peritonitis, or of acute gangrenous appendicitis with cloudy peritoneal fluid, culture of which yielded no bacterial growth. It is felt that the pathologic condition found at operation provides a more reliable basis for the diagnosis of appendical abscess than do the preoperative findings alone. In this series of cases, for instance, there are many patients in whom there was no palpable mass either at the time of the initial examination or after induction of anesthesia.

As judged by these standards, 149 cases were selected out of a total of about 3,600 appendectomies. They were studied chiefly from the viewpoint of operative treatment and immediate and late results of

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surgery. The diagnostic aspects of the condition are not emphasized. Much has been written about this aspect and on the prognosis, and an excellent article with a careful analysis of these points has recently been published by Rogers and Faxon.[1]

The 149 patients constitute a cross section of the population of the metropolitan area. They ranged in age from 5 months to 76 years. and were distributed throughout the decades as indicated in Table I.

TABLE I

| DECADE | NUMBER OF CASES | DEATHS |
|---|---|---|
| 1 | 23 | 1 |
| 2 | 22 | 1 |
| 3 | 33 | 1 |
| 4 | 23 | 1 |
| 5 | 19 | 1 |
| 6 | 16 | 1 |
| 7 | 10 | 1 |
| 8 | 3 | 0 |

There were seven deaths in the series, a postoperative mortality of 4.7 per cent. The causes of death were varied. Two patients died of generalized peritonitis; in one the peritonitis was present at the time of operation, in addition to the abscess, in the other there was probably a postoperative spread of the infection. Two patients died of massive pulmonary embolus seven and eight days, respectively, after operation. Two others developed mechanical intestinal obstruction and died, both after having had jejunostomies as secondary operations. There was one death from bronchopneumonia.

An analysis of these seven fatalities yields the impression that two might have been avoided had different treatment been carried out. In one of the two cases of generalized peritonitis the patient was subjected to appendectomy, despite the fact that the position and condition of the appendix made its removal difficult and time-consuming, and undoubtedly resulted in spread of the infection. It would probably have been wiser had the surgeon been content with simple drainage of the abscess. The patient with pneumonia probably would have had a better chance of survival had the sulfonamide drugs been available at the time.

It is the general policy in this clinic to subject the patient to operation as soon as the diagnosis of appendical abscess is made. Thus, the great majority of patients in this series were operated upon within six hours of their admission.

If the appendical abscess was complicated by other coexistent conditions such as diabetes, cardiac disease, or fluid imbalance, operation was delayed sufficiently long to allow such conditions to be controlled. In a few cases in which the diagnosis was obscure, several days elapsed while diagnostic studies were carried out.

The incision of choice was the McBurney (or gridiron) type and it was used in all cases save a few in which failure to arrive at a definite diagnosis before operation warranted exploration through a paramedian incision.

General anesthesia (ether, nitrous oxide and ether, or cyclopropane) was used in the majority of cases, although spinal or local was used in a few.

Once the abdomen was opened, the type of procedure was dictated by two factors: (1) relative ease with which the appendix could be removed, and (2) the general condition of the patient before and during operation. The procedure of choice was appendectomy with drainage. However, if it was judged that removal of the appendix would be difficult and would necessitate much manipulation and trauma with the danger of the spread of infection, the surgeon in most cases simply evacuated the pus and inserted drains. By the same token, if the condition of the patient was very poor, so that prolonged anesthesia and manipulation would have been hazardous, simple drainage was performed.

According to these indications appendectomy was carried out in eighty-nine patients (60 per cent) of the series and simple drainage in sixty (40 per cent).

In the group of patients treated by appendectomy and drainage there were three deaths, a mortality rate of 3.4 per cent. One patient died of generalized peritonitis with paralytic ileus, one of mechanical obstruction due to volvulus of a loop of ileum without gangrene, and the third of massive pulmonary embolus (see Table II).

TABLE II

POSTOPERATIVE DEATHS

| HOSPITAL NUMBER | AGE IN YEARS | DURATION OF SYMPTOMS (DAYS) | OPERATIVE PROCEDURE | CAUSE OF DEATH |
|---|---|---|---|---|
| 76805 | 13 | 3 | Appendectomy with drainage | Mechanical obstruction |
| 258728 | 30 | 4 | Appendectomy with drainage | Peritonitis and ileus |
| 288225 | 63 | 2 | Appendectomy with drainage | Embolus |
| 67195 | 2 | 10 | Incision and drainage | Peritonitis and ileus |
| 80770 | 52 | 5 | Incision and drainage | Mechanical obstruction |
| 164354 | 32 | 10 | Incision and drainage | Pneumonia |
| 301476 | 43 | 10 | Incision and drainage | Embolus |

Four of the sixty patients treated by drainage alone died, a mortality rate of 6.6 per cent. The causes of death were strikingly parallel to those in the former group. Peritonitis, demonstrated at autopsy to have been present at the time of drainage of the abscess, mechanical obstruction, and embolus again were the conditions leading to death. In addition, one patient died of pneumonia. The relatively higher

mortality rate in the second group is likely to be misleading unless it is understood that, in general, the patients selected for simple drainage were those who were in the poorest condition before operation.

### COMPLICATIONS

Excluding the fatal complications described above, there were forty-five complications in thirty-nine patients. The discrepancy of figures is due to the fact that six patients each had two complicating conditions. Grouped according to the type of operation there were thirty-one complications following appendectomy and fourteen after simple drainage (see Table III). The larger number of fecal fistulas in the second group of cases would be expected, since in them no attempt was made to close the opening in the bowel. All except two fistulas closed spontaneously before the patient was discharged from the hospital. One of these required closure after five months, at which time the appendix was removed; the other persisted intermittently for two years after operation, at which time the patient died of pyelonephritis. If the complication of fecal fistula is excluded, the numbers of complications are reduced to twenty-eight in the first group and six in the second. Thus, it becomes apparent that the morbidity is strikingly less following incision and drainage than after appendectomy with drainage.

TABLE III

POSTOPERATIVE COMPLICATIONS

| COMPLICATION | OPERATIVE PROCEDURE | |
|---|---|---|
| | APPENDECTOMY WITH DRAINAGE | INCISION AND DRAINAGE |
| Pelvic abscess | 9 | 0 |
| Fecal fistula | 3 | 8 |
| Pulmonary infarct | 5 | 0 |
| Bronchopneumonia | 6 | 0 |
| Intestinal obstruction | 1 | 0 |
| Peritonitis | 2 | 0 |
| Parotitis | 2 | 0 |
| Empyema | 1 | 0 |
| Renal infarct | 1 | 0 |
| Wound abscess | 1 | 4 |
| Pyelonephritis | 0 | 1 |
| Jaundice with fever* | 0 | 1 |

*Attributable to sulfanilamide.

It is to be noted that postoperative (incisional) hernias are arbitrarily omitted as postoperative complications. Although, undoubtedly, hernias are technically caused by the operative procedure, it is considered logical, from the practical standpoint, to list them separately, since in no case did they influence the early postoperative course. There were twenty-two such hernias in this series, an incidence of 15 per cent. The fact is of interest that of these only six followed appendectomy with drainage, while sixteen occurred after simple incision and drainage. All hernias were at the site of the McBurney incision.

### SUBSEQUENT COURSE OF PATIENTS SUBJECTED TO INCISION AND DRAINAGE WITHOUT APPENDECTOMY

A study of the subsequent course of the patients in whom the appendix was not removed at the time the abscess was drained is of interest.

Twenty-eight of the patients were subjected to elective appendectomy at intervals varying from two months to four years after the original operation. There were no deaths in this group.

Ten patients were readmitted with a recurrence of acute appendicitis at the time intervals following the primary procedure shown in Table IV. All of these, save one who had simple acute appendicitis, were found to have perforation and recurrent abscess requiring operation. Two of the patients had two recurrent abscesses. Again there were no deaths.

TABLE IV

RECURRENCE AFTER SIMPLE DRAINAGE

| AGE IN YEARS | INTERVAL AFTER ORIGINAL OPERATION | CONDITION FOUND AT SECONDARY OPERATION |
|---|---|---|
| 12 | 1½ mo. and 1 mo. | Appendical abscess |
| 57 | 4 mo. | Appendical abscess |
| 35 | 5 mo. | Appendical abscess |
| 22 | 6 mo. | Appendical abscess |
| 63 | 7 mo. | Appendical abscess |
| 55 | 7 mo. | Appendical abscess |
| 50 | 11 mo. | Appendical abscess |
| 56 | 11 mo. | Acute appendicitis |
| 9 | 18 mo. | Appendical abscess |
| 4 | 6 yr. | Appendical abscess |

A third group of patients, fifteen in number, have not had the appendix removed at operation, either because the patient refused to enter for appendectomy or because appendectomy was thought to be contraindicated by age or associated condition. The time that has elapsed since incision and drainage varies among these fifteen patients from eight months to seven years. None of them has had symptoms suggestive of appendicitis. One other patient, who had a persistent fecal fistula, died of pyelonephritis and diabetes two years after incision and drainage. Two patients have been lost to the follow-up clinic.

According to these figures, twenty-five patients who had simple drainage of an appendical abscess and have not had elective appendectomy are known to be living. Of these twenty-five, ten (40 per cent) have had recurrence of their disease requiring operation under unfavorable circumstances with added hazards.

It is of note that in this group of ten patients the recurrence in eight cases developed within the first year after incision and drainage. The ages of the patients having recurrences varied widely, four of them being 25 years of age or younger, and five being 50 or older. Thus, it

is impossible to predict, according to age, which patients are likely to develop recurrence. Elective appendectomy should, therefore, be performed in all patients whose condition does not contraindicate this procedure.

It is not possible to establish an arbitrary limit of time within which elective appendectomy should be performed. However, it is advisable to remove the appendix as soon as possible after recovery from the original procedure. A two or three months' interval is adequate time to allow for resolution of the inflammatory process in the peritoneal cavity. Therefore, the optimal time for elective appendectomy is three months after the incision and drainage.

### USE OF SULFA DRUGS

Of the 149 cases in this series, only 26 were treated by the oral or parenteral administration of the sulfonamides, sulfanilamide having been given to 11 and sulfadiazine to 15 patients. In this group there were two deaths, a mortality rate of 7.7 per cent. The group obviously is too small to allow for fair evaluation of this adjunct of operative treatment.

### SUMMARY

1. A series of 149 consecutive cases of appendical abscess is reviewed.

2. Of the total 149 cases, 60 per cent of the patients were subjected to appendectomy with drainage, 40 per cent to incision and drainage alone. There was a general mortality of 4.7 per cent.

3. Of the patients whose appendices were not removed either at the time of drainage of the abscess or at a secondary elective operation, ten, or 40 per cent, developed a recurrent abscess.

4. The number of patients given sulfonamide drugs is too small to allow a fair evaluation of their effect.

### REFERENCE

1. Rogers, Horatio, and Faxon, Henry H.: A Statistical Study of 671 Cases of Appendiceal Peritonitis, New England J. Med. 226: 707, 1942.

# INTUSSUSCEPTION—NINETY-TWO CASES IN INFANCY AND CHILDHOOD

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ACUTE intestinal intussusception is one of the most important surgical emergencies in the early years of life. An admirable discussion of the subject has been presented by Ladd and Gross in their recent text. Their remarkable improvement in mortality for this frequently fatal disease stimulates a review of additional cases from other clinics and hospitals in an effort to achieve a universal reduction in mortality.

The cases have been reviewed from two institutions which are affiliated with the University of Cincinnati and are supplied by the same rotating surgical house staff, the Children's Hospital of Cincinnati and the Cincinnati General Hospital. The records of the former include both private and ward patients under 15 years of age. Those of the latter represent only ward patients in the same age group.

The review covers a sixteen-year period from Jan. 1, 1927, to Dec. 31, 1942. During this time 59 patients with 60 intussusceptions were operated upon in the Children's Hospital and 31 patients with 32 intussusceptions were operated upon in the General Hospital, an average of 6 cases per year for the two institutions.

## AGE, SEX, AND RACE INCIDENCE

Intussusception is primarily a disease of infants in the first year of life. Of the patients in this study, 62.5 per cent were between 2 and 11 months of age. The peak of the age incidence was at 5 months. The youngest child was 1 month and 28 days of age, the oldest was 15 years. All but 2 were less than 8 years old. The age incidence by months and by years is essentially comparable to that reported by others.[2, 9, 10, 12]

The sex incidence also is in accord with that found by other reporters.[3, 4, 7, 9, 10, 13] Sixty-two per cent of the patients were boys and 38 per cent were girls.

At the Children's Hospital all but 2 patients were white. At the General Hospital there were 17 white and 15 Negro.

## SYMPTOMATOLOGY

The often emphasized cardinal symptoms of intussusception are: intermittent colicky abdominal pain, vomiting, and the passage of bloody

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stools. This triad was found in 39 or less than one-half of the 86 cases for which an adequate history was recorded.

There was a manifestation of abdominal pain in 73.3 per cent of the cases. Ladd and Gross describe the recurrent colicky abdominal pain as an almost universal complaint. The onset is usually sudden. The pain is of an intermittent and colicky nature, coming on in paroxysms every ten to thirty minutes and lasting only several seconds. Between the paroxysms the child may be content and apparently comfortable.

Vomiting usually appears early and in many small infants was the first sign of illness. Vomiting was recorded in 89.5 per cent of the records and was noted in 21 cases when no manifestation of pain had been recognized. Gordon elicited this complaint in all infants and in 90 per cent of children and adults with intussusception.

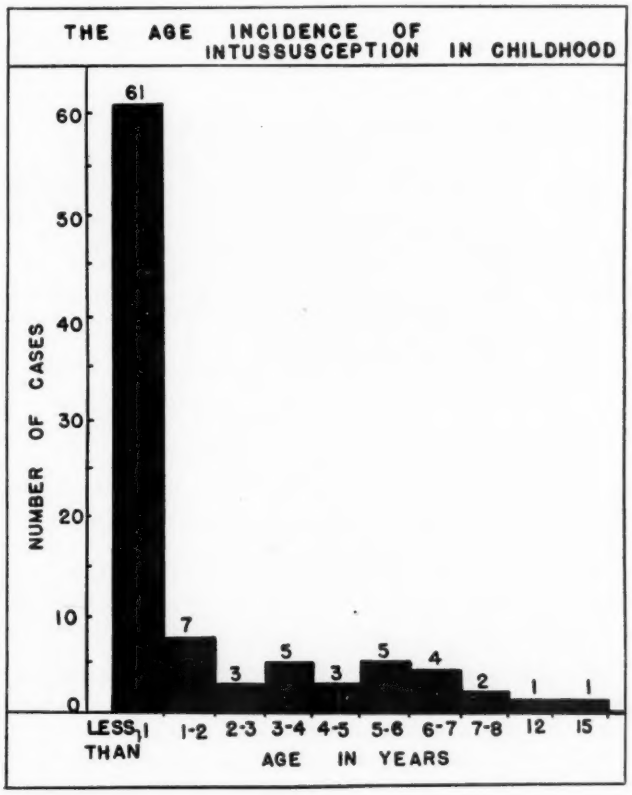


Fig. 1.

A history of blood in the stool, hematochezia, was noted in only 70.9 per cent of the cases. However, blood was noted on the examiner's finger after rectal examination in 6 additional cases. The history may be one of gross hemorrhage or only of bright red staining on the diaper. Ladd and Gross anticipate the passage of bloody stools by about 85 per cent of the patients, but warn that this symptom may be absent if the

patient is seen in the first twelve to fourteen hours of illness. In other reviews, hematochezia has been described in from 70 to 100 per cent of the cases.[2, 10, 13]

The absence of hematochezia is not necessarily a good prognostic sign, for of 19 patients without blood in the stool, 8 died. Of 67 with blood in the stool, only 17 died.

Although the classical triad of symptoms was reported in less than one-half of the cases, two of the three cardinal symptoms were noted in more than 90 per cent.

The average duration of symptoms at the time of admission to the hospital was 41.3 hours, at the time of operation 47.5 hours. The average delay between admission and operation was thus 6.2 hours. The relation of these factors to mortality will be discussed later.

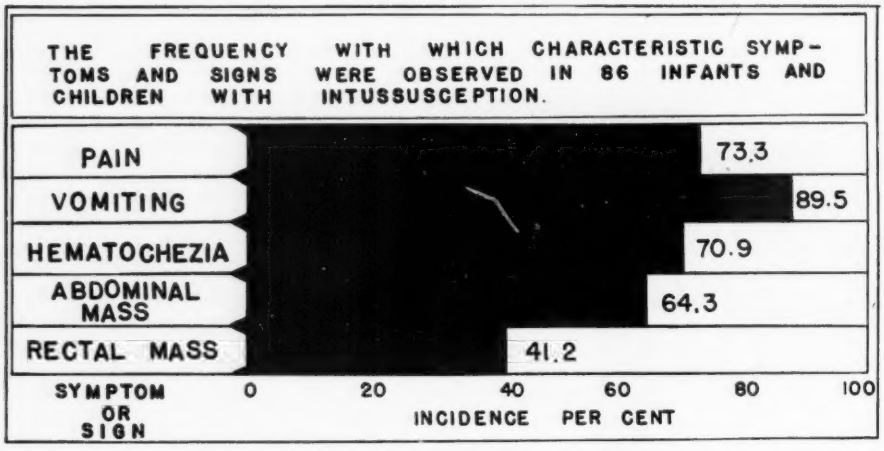


Fig. 2.

PHYSICAL FINDINGS

It is well known that intussusception is apt particularly to occur in well-nourished, healthy infants and children. This was found to be true in the majority of instances. Early in the illness the child may not appear to be very ill, especially if seen between the paroxysmal attacks. However, if intestinal obstruction remains present for many hours the child becomes obviously ill.

Five patients not included in this report were admitted to the Children's Hospital in a moribund condition too sick for operation. All died in less than three hours after admission. Three of these patients had had symptoms for only twenty-four hours, one for three days, and one for seven days.

The so-called cardinal finding on physical examination is a palpable abdominal mass. This was recorded in only 64.3 per cent of the cases. Other reporters describe a mass in from 50 to 85 per cent of the cases.[2, 10, 12, 13] It is usually described as firm and frequently as sausage

shaped. Kahle wonders whether the mass is typically sausage shaped or whether this is a convenient term which has passed down from one generation of physicians to the next. The mass may vary in size from that of a walnut to that of an orange, depending upon the age of the patient. The mass was described in all quadrants of the abdomen but was most frequently found in the right upper quadrant. It was observed sometimes to become tense during a paroxysm of pain.

Rectal examination was recorded in only 68 cases and a mass was felt in only 28, or 41.2 per cent, of these. However, the importance of rectal examination must be emphasized. In 16 cases a mass was felt by rectal examination when none could be felt by abdominal palpation. This is likely to be true particularly when the abdomen has become distended. Furthermore, as was already mentioned, blood may be found on rectal examination when there is no history of bloody stools.

This series of cases is too small to evaluate the significance of fever. In 39 cases the rectal temperature on admission was less than 100° F. In 31 cases it was between 100 and 102° F. and in 14 cases it was more than 102° F.

### LABORATORY STUDIES

The white blood cell count on admission was less than 10,000 in 16 cases, between 10,000 and 20,000 in 31 cases, and more than 20,000 in 8 cases. Other laboratory studies were not recorded in sufficient number to warrant their discussion.

### ROENTGENOLOGIC FINDINGS

Roentgenologic studies were made in only 34 of the cases. In 29 of these only a simple film of the abdomen was made. Gas accumulation was described in 21 cases and 8 were reported as negative. Fluoroscopic examination with a barium enema was used in only 5 cases. Typical findings were reported and the diagnosis strengthened in 4 cases. The fifth case was a lesion of the ileo-ileal type in which the intussusceptum had not progressed as far as the cecum. This patient presented such characteristic symptoms and signs that operation was done in spite of the negative x-ray findings.

### TREATMENT PRIOR TO ADMISSION

A history of home treatment by catharsis was obtained in 18 cases and by enemas in 22 cases. However, a definite relation to mortality rate, as can be so well shown in acute appendicitis was not demonstrable.

### CONSERVATIVE TREATMENT

It has been our opinion that every case of intussusception is a surgical emergency and the patient should be operated upon as soon as the diagnosis is made. We have had no experience with nonoperative methods of reduction. However, one cannot blind himself to the excellent results obtained by Hipsley with preliminary injections of saline solution

per rectum prior to operation. Certainly, to apply gentle pressure on the apex of the intussusceptum from within the bowel is a rational method of attempting reduction. The chief objection to hydrostatic reduction is that the operator is uncertain whether or not reduction has been accomplished. After many years of experience Hipsley has found certain signs of reduction fairly accurate.[5] However, if there is any doubt, reduction is verified by operation, frequently through a McBurney incision. If reduction is not accomplished easily the hydrostatic method is abandoned and operation undertaken.

Most surgeons, particularly in the United States, condemn any method of reduction other than operative. Jones adopts a more liberal attitude and concedes that one should not disregard the value of an attempt at reduction with hydrostatic pressure, especially in early cases, but warns that this method may be unwise when the condition has been present for twenty-four hours.

### PREOPERATIVE TREATMENT

If the child is dehydrated, toxic or acidotic, fluid and electrolyte balance are restored rapidly by the administration of intravenous or subcutaneous fluids. These and blood or plasma transfusions may be continued during operation if the child's condition warrants. Atropine or scopolamine is given by hypodermic injection in proper preanesthetic dosage.

### ANESTHESIA

Open drop ether is preferred to local anesthesia unless it is specifically contraindicated. Not only does local anesthesia afford poorer relaxation and greater technical difficulty but it also renders the operation more shocking to these frequently tiny patients. Ether anesthesia is also preferred by Ladd and Gross, Mayo and Woodruff, Wyatt, and Miller and Workman. All but 7 patients in this series were operated upon under ether anesthesia.

### OPERATIVE TREATMENT

All of the patients in this review were operated upon. A right rectus incision was used in 80 cases. A left rectus, a midline, and a McBurney incision were used in 3 cases. In 3 cases the type of incision was not recorded. Ladd and Gross have found the most difficult part of the operative procedure to be generally in the reduction of the last portion of the lesion in the region of the cecum. Hence, an incision which affords a good exposure of this area is preferable to one made over the palpable mass.

Reduction of the intussusception is performed by gentle pressure backward along the intussuscipiens attempting to squeeze out the intussusceptum. Traction should be used only with great care. Small tears in the serosa are not particularly serious and should be repaired im-

mediately, but perforation during reduction is a grave and sometimes fatal technical error, even though it is recognized and repaired.

Once reduced, the bowel may appear very dusky or angry red due to edema and hemorrhage. A few moments spent in observation after the application of warm saline pads will give evidence of viability by improvement in color and return of peristalsis.

The following operative procedures were used in the patients studied. Reduction was accomplished and was all that was done in 25 cases with a mortality rate of 40.0 per cent. In 16 other cases, in addition to reduction, some attempt was made to fix the bowel and prevent recurrence. This was done either by suturing the ileum to the cecum, or by suturing the ileum, cecum, or ascending colon to the parietal peritoneum. The mortality in this group was 25.0 per cent. In 32 cases appendectomy was done with an associated mortality of 3.1 per cent. Obviously, one cannot conclude that the mortality rate is lower with than without appendectomy. Appendectomy is more apt to be done when the lesion is mild or readily reduced and when the patient's condition is not critical. In severe cases it is done only when the appendix exhibits definite irreversible impairment of blood supply. Reduction and Meckel's diverticulectomy were done in 2 cases with one death. One fatality followed closure of a perforation made during reduction. In one case a lymph node, thought to be the cause of the intussusception, was removed without complications.

Resection and primary anastomosis was done in 7 cases with a mortality of 42.9 per cent. Five of these patients had end-to-end anastomosis, one had a side-to-side anastomosis, and in the other case the type of anastomosis was not specified. The ages of the patients who survived were 10, 10, 31, and 39 months. Those who died were 7, 30, and 33 months of age.

Resection was accomplished by a Mickulicz type of procedure or double enterostomy in 5 patients, the ages of which were 4, 5, 9, 16, and 60 months. All of these patients died.

In 2 patients, 5 months and 15 years of age, resection was done, the end of the distal bowel closed, and a proximal ileostomy made. Both patients died.

In one patient, 7½ years of age, an ileosigmoidostomy was made around the irreducible mass by side-to-side anastomosis leaving the mass in situ. This patient also died.

Thus, there were 77 cases in which reduction was accomplished without major bowel resection, with 17 deaths, a mortality rate of 22.1 per cent; and 14 cases in which some form of major resection was necessary, with 10 deaths, a mortality of 71.5 per cent. In the latter group the results with resection and primary anastomosis were better than with the establishment of an enterostomy.

Most reporters are agreed that bowel resection should never be done unless absolutely necessary. The mortality of resection in infants is estimated at from 70 to 100 per cent.[3, 9, 14, 15] However, what type of resection should be done when it is necessary is still unsettled and our figures are too small to shed much light on the discussion. Ladd and Gross found that the proportion of successful resections, even in a collective review of the literature, is inadequate to determine whether primary anastomosis or double enterostomy is the procedure of choice. They found that the successful resections were treated, in the majority of instances, by primary anastomosis of the intestine but their own records tend to show that the Mikulicz procedure gives a little better chance of recovery.

In our opinion, the procedure to be used must be chosen for the individual case. The operator must make every effort to reduce the lesion, even though it may require one-half hour, rather than to resort to unnecessary resection. On the other hand, valuable time must not be wasted in attempting to reduce an irreducible or gangrenous lesion. If resection is necessary and the patient's condition will permit, primary anastomosis is preferred. On the other hand, the Mikulicz procedure can be more rapidly executed and its use, when the patient's condition is critical, may mean the difference between a live child with an enterostomy and a dead one with an anastomosis. However, infants and young children do not tolerate well the subsequent loss of succus entericus and every effort must be made to maintain fluid, protein, and electrolyte balance. Restoration of bowel continuity should be established as soon as feasible.

Woodhall reported two successful resections in which he made a lateral anastomosis around the lesion at the same time he did the Mikulicz procedure. In this manner continuity of the bowel was re-established immediately. We have had no experience with this procedure.

### MORTALITY RATE

At the Children's Hospital 60 operations were followed by 18 deaths, a mortality of 30.0 per cent. At the General Hospital 32 operations were associated with 10 deaths, a mortality of 31.3 per cent. The average mortality for the entire series from both institutions for the sixteen-year period was 30.4 per cent.

Kahle reports a mortality rate of 52.5 per cent in infants and children. Mayo and Woodruff reported a mortality of 23.6 per cent, Gordon of 22.7 per cent, Wakely and Atkinson of 10.0 per cent. Grigsby and Kaplan of 22.0 per cent, Hipsley of 4.9 per cent, and Ladd and Gross of 31.2 per cent.

There has been a conspicuous improvement in mortality among the cases herein reported during the last five years. Since 1937, 22 patients have been operated upon at the Children's Hospital with one death, a mortality of 4.5 per cent; and 14 have been operated upon at

the General Hospital with 2 deaths, a mortality of 14.3 per cent. The combined mortality for both institutions during this period was 8.3 per cent.

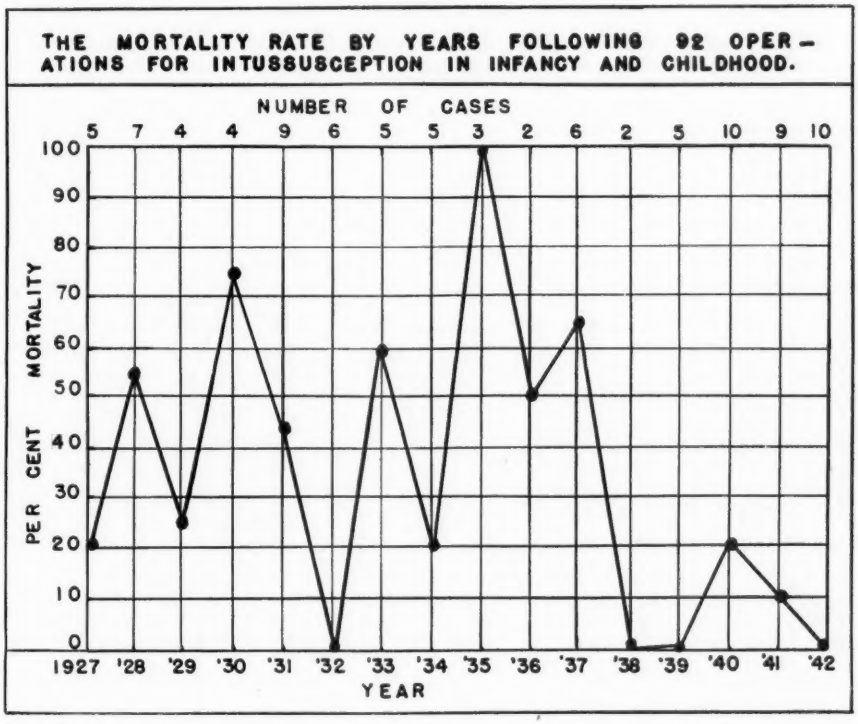


Fig. 3.

Similar improvement in recent years has been obtained by others. Gordon reported 16 consecutive cases with a 6.25 per cent mortality. Ladd and Gross reported a mortality of 14.0 per cent in 90 cases and in their text report 12 consecutive cases without a death.

## FACTORS AFFECTING MORTALITY RATE

The three most important factors in the lower mortality figures for the last five-year period are probably: (1) earlier hospitalization and fewer cases of delayed operation, (2) fewer bowel resections, and (3) improved pre- and postoperative care.

This report again indicates the dangers of delayed operation for intussusception. Only 19 per cent of the patients in the last five-year period had allowed symptoms to progress for more than 48 hours before coming to operation, while 44 per cent of those seen in earlier years were operated upon after the second day of illness. Not only was the average duration of symptoms on admission less in the recent group (35.8 hours as compared with 45.3 hours for the earlier cases) but there was also less delay between admission and operation (3.9 hours as compared with 7.8 hours).

TABLE I

THE OPERATIVE PROCEDURES USED AND THE ASSOCIATED MORTALITY RATES IN 92 CASES OF INTUSSUSCEPTION

| OPERATIVE PROCEDURE | NO. OF CASES | DEATHS | PER CENT MORTALITY |
|---|---|---|---|
| Reduction | 77 | 17 | 22.1 |
| Reduction only | 25 | 10 | 40.0 |
| Fixation | 16 | 4 | 25.0 |
| Appendectomy | 32 | 1 | 3.1 |
| Diverticulectomy | 2 | 1 | 50.0 |
| Closure of perforation | 1 | 1 | 100.0 |
| Removal of lymph node | 1 | 0 | 0.0 |
| Resection | 14 | 10 | 71.5 |
| Primary anastomosis | 7 | 3 | 42.9 |
| Double enterostomy | 5 | 5 | 100.0 |
| Single enterostomy | 2 | 2 | 100.0 |
| Anastomosis around mass | 1 | 1 | 100.0 |
| Total | 92 | 28 | 30.4 |

Recently there have been more successful reductions and fewer bowel resections. Only 11 per cent of the cases seen in the last five years have required resection. This figure was 18 per cent in the earlier group.

Shock, toxemia, and dehydration are recognized as the most important complications and the most frequent cause of death in cases of intussusception. Although we cannot show it statistically, there is little doubt that improved preoperative care and postoperative care have contributed materially to the recent reduction in mortality. Both hospitals now receive the benefit of close cooperation between the surgical and pediatric services. Recently, the facilities of a fully equipped blood bank have made the more frequent use of whole blood and plasma transfusions easy. Care in re-establishing fluid and electrolyte balance before operation and maintaining it during and after operation with intravenous and subcutaneous administration of fluids, and the more frequent use of oxygen therapy have all contributed to the improved results.

TABLE II

THE RELATION BETWEEN DURATION OF SYMPTOMS AT THE TIME OF OPERATION AND THE MORTALITY RATE IN 86 CASES OF INTUSSUSCEPTION

| DURATION OF SYMPTOMS | NO. OF CASES | DEATHS | PER CENT MORTALITY |
|---|---|---|---|
| Less than 24 hr. | 38 | 4 | 10.5 |
| 24-48 hr. | 19 | 3 | 15.8 |
| 2-3 days | 6 | 2 | 33.3 |
| 3-4 days | 7 | 3 | 42.9 |
| 4-5 days | 5 | 3 | 60.0 |
| 5-6 days | 3 | 2 | 66.7 |
| 6-7 days | 4 | 3 | 75.0 |
| More than 7 days | 4 | 4 | 100.0 |

The ileo-ileal lesions were associated with the highest mortality (62.5 per cent) and the colo-colic lesions with the lowest (25.0 per cent). The mortality for ileo-colic lesions was 25.4 per cent, and for ileo-ileo-colic lesions, 44.4 per cent. No instances of multiple or of retrograde invagination were encountered.

## COMPLICATIONS

Twenty-three of the 28 deaths occurred during the first twenty-four postoperative hours and we have come to believe that if a patient survives the first twenty-four hours after operation he is apt to recover. These early deaths are generally attributed to shock and toxemia.

Complications included 14 cases of diarrhea, 8 upper respiratory infections, 8 cases of otitis media, 5 cases of pneumonia, 3 wound infections, 3 eviscerations, 2 cases of pulmonary edema, 2 cases of postoperative obstruction requiring operative release of adhesions, 2 cases of acute bronchitis, and 1 each of insulin shock, chicken pox, scarlet fever, intraenteric hemorrhage, atelectasis, fecal fistula, and intestinal obstruction of unknown cause thought to be the result of a recurrence with subsequent spontaneous resection.

Recurrence of the lesion was confirmed in 3 cases. Two of these patients were operated upon a second time, ten months and one year, respectively, after their first operation. A third patient died 5 hours after operation and was found to have a recurrent ileo-colic lesion which had extended around to the splenic flexure after being reduced from the sigmoid area at operation. This is believed to be the earliest recurrence to be reported.

TABLE III

THE TYPES OF LESION ENCOUNTERED IN 92 CASES OF INTUSSUSCEPTION AND THEIR RELATIVE MORTALITY RATES

| TYPE OF INTUSSUSCEPTION | NO. OF CASES | DEATHS | PER CENT MORTALITY |
|---|---|---|---|
| Ileo-ileal | 8 | 5 | 62.5 |
| Ileo-ileo-colic | 9 | 4 | 44.4 |
| Ileo-colic | 67 | 17 | 25.4 |
| Colo-colic | 8 | 2 | 25.0 |
| Total | 92 | 28 | 30.4 |

## CONCLUSIONS

1. Ninety-two cases of intussusception with the patients operated upon in infancy and childhood have been reviewed from the Children's Hospital of Cincinnati and the Cincinnati General Hospital.

2. The classical symptom complex was described in less than one-half of the cases.

3. Of every 10 cases, pain was described in 7, vomiting in 9, and hematochezia in 7. At least two of these symptoms were noted in nearly all of the cases.

4. Of every 10 cases, a palpable abdominal mass was described in 6 and a rectal mass in 4.

5. The methods of treatment are described and the results of different methods compared.

6. Factors which have effected a recent reduction in mortality rate are discussed.

7. A lower mortality will be obtained only when the pediatricians are constantly on the alert for cases of intussusception, by prompt hospitalization and operation, by careful and individual selection of the operative procedure, and by intelligent cooperation between the pediatricians and surgeons in the preoperative and postoperative care.

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# MASTITIS OBLITERANS

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IN RECENT years low-grade inflammatory lesions of the breast simulating cancer clinically, and sometimes microscopically,[1, 6, 7, 9, 10, 17] have received much attention by pathologists and surgeons. In addition to simple and subacute mastitis and traumatic fat tissue necrosis, there has been a picture called plasma cell mastitis discussed and described at length. However, there is a less known low-grade inflammatory lesion of the breast which is characterized by an obliterating process of the milk ducts called mastitis obliterans, and this condition likewise simulates cancer in its clinical picture.

In 1909, Alexandra Ingier[13] published the first description of this picture under the name of "Mastitis Obliterans." She referred to previous studies by Langhans,[16] who as early as 1873 had called attention to the obliteration of the milk passages in tissue associated with cancer of the breast.

In 1905, Samelson-Kliwansky[20] published an article entitled "A Contribution to the Knowledge of Mammary Cyst With Butterlike Contents." The clinical data relating to his specimen were not reported. The cross section of the specimen showed a "firm, granular, whitish, semitranslucent tissue with numerous small openings from which, upon slight pressure, yellowish-green, partly calcified plugs came forth." The hollow spaces in the specimen were ducts 1 to 2 cm. long and 0.25 to 1 mm. in diameter. Microscopically, the butterlike material consisted of degenerated epithelium and its products. He reasoned that inflammatory connective tissue had led to the obliteration of the ducts and had been followed by degeneration of the epithelium which in some areas was in the stage of proliferation. Giant cells and cholesterol crystals were present in the milk passages, and these passages were surrounded by numerous areas of lymphocytic foci.

Ingier's case was as follows.

A woman 43 years of age had given birth to a child, and while nursing this baby, a mammary abscess developed in the right breast which was incised. Approximately one month after her discharge from the hospital, a nodular mass the size of a small hen egg developed in the right breast and was excised. The tissue excised was quite firm and composed of lobules slightly larger than those of the normal breast. The cut surface showed yellowish white flecks and stripes, 1 to 2

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mm. long and 0.5 mm. in diameter. A yellowish white secretion could be expressed from the tissue. Microscopically, many of the acini showed their lumina obliterated and the membrana propria was often destroyed. Lymphocytes were present between the proliferated epithelial cells and diffusely scattered throughout the lobules. The epithelium showed degenerative changes such as fat droplets, indistinct outline, and badly stained nuclei. There were many multinulceated giant cells. In addition to the acini being closed, the lumina of the larger ducts and their branches were occasionally obliterated, and their walls appeared to be formed by three layers as follows: A peripheral layer, highly infiltrated with lymphocytes, associated with an increase of elastic fibers; a medial layer consisting of round spindle-shaped polyhedral and branched cells arranged radially with relation to the lumen; an internal one consisting of epithelial cells showing marked degenerative and proliferative changes which were limited by the medial layer and often showed loss of the membrana propria.

In 1910, Hoerz[12] discussed a case of mastitis obliterans as follows.

A woman 43 years of age had borne sixteen children and had nursed all of them from her left breast. Her right one had not given sufficient milk. One and one-half years after the birth of her last child, she received a blow against the nonfunctioning right breast. Two weeks later an acute mastitis was present, associated with chills. The temperature rise cleared up in a few days, but the tenderness, redness, and swelling persisted. The nipple became retracted, and there developed a lump the size of a fist with indistinct boundaries but not fixed to the skin. One month later part of the large mass had disappeared, but there remained a diffuse hardening in the lower, inner quadrant with some attachment to the skin. She underwent a radical mastectomy because cancer was suspected. The gross and microscopic examination of the tissue removed showed the same changes as in Ingier's case but in addition, ray funguslike clusters of fatty acid crystals surrounded by foreign body granulomas were present.

During the following two decades, mastitis obliterans seems to have been forgotten. In 1923, Keynes,[15] in a publication on chronic inflammatory mastitis, described a case of acute exacerbation of chronic mastitis during pregnancy and attributed the fibrosis of the ducts and the disappearance of their epithelium to the retention of milk. Illustrations in his publication coincide with those of mastitis obliterans.

In 1933, Schultz[22] published a discussion of a case of mastitis obliterans with numerous photomicrograms and described in details the histologic picture but did not stress the clinical data. He considered complete obstruction of the ducts to be rare and emphasized the fact that the same process occurred rather commonly in chronic mastitis. In considering the relationship of the clinical picture to malignancy, Schultz stated that mastitis obliterans could begin as an acute or subacute inflammation which became chronic; however, in some cases the acute and subacute stages were not apparent and could only be developed through the history.

One of us (R.D.G.) observed the following case of mastitis obliterans.

Mastitis obliterans occurred in a colored woman 57 years old. Her family history was not contributory. She has two living children and has had three miscarriages. In 1918, hysterectomy was performed because of tumors in the uterus.

In 1930, she had a bilateral subtotal thyroidectomy performed for toxic adenoma. On admission to St. Vincent's Hospital, her chief complaint was enlargement of the left breast which she had been observing for two years. During the two weeks prior to admission the breast had become somewhat tender and she felt shooting pains through the area involved. There was dyspnea on exertion, and standing for a long period of time produced swelling of the ankles. There was a slight tremor of her hands. Her temperature ranged from 98.6 to 100° F. Blood pressure was 174 systolic and 98 diastolic. She thought she had lost approximately ten pounds in weight during the past two years. Her left breast was enlarged with a firm infiltrated mass under the nipple and some induration of the skin. The nipple reflex was lost and in the axilla there were some enlarged lymph nodes which were tender. Radiologic examination revealed no metastases to the lungs or to the skeletal framework.

*Laboratory Findings on Admission.*—Urine was positive for sugar, a trace of albumin, and a few pus cells. After four days on a diabetic diet (carbohydrate, 120; fat, 80; protein, 60), the urine became negative for sugar and the blood sugar was 108 mg. The blood picture disclosed hemoglobin 78 per cent, R.B.C. 4,116,000, W.B.C. 11,500, polymorphonuclears 85 per cent, and lymphocytes 15 per cent. The non-protein nitrogen was 40 mg. per 100 c.c. of blood and she had a positive Wassermann.

The diagnosis of a subacute mastitis was confirmed from a clinical viewpoint, yet the tumor mass gave a decided suspicion of cancer. At operation a simple mastectomy was performed and rapid frozen section showed no evidence of cancer. The gross specimen showed an infiltrated hard tumor mass 7 cm. in diameter and on section showed many areas of degeneration with thick purulent secretion. The gross examination of the specimen in the pathologic laboratory was breast, 21 by 14 by 3 cm. in size, areola 6 cm. in diameter. There was very little, if any, retraction of the nipple. Under the nipple there was a hard mass with indistinct boundaries, which was adherent to the overlaying skin. On cross section, there was no well defined tumor; throughout the entire mammary gland and especially throughout the mass below the nipple, pressure caused yellowish creamy material to ooze from numerous small openings. The mammary tissue was white in color and decidedly more dense and firm in the subareolar region with this tissue reaction fading into the surrounding fat. Within the mass there were yellowish stripes and spots and the ducts appeared white but showed a yellow center.

*Microscopic Examination.*—Blocks of tissue examined from different areas of the mass showed lymphocytic infiltration, especially marked about the smaller and larger ducts. There was very little plasma cell infiltration. The terminal ducts showed budlike proliferation and revealed hyperplasia and desquamation of their epithelial cells and occasionally giant cells were present. The larger ducts presented granulation tissue in their walls. The fibroblasts were radially arranged forming a thick ring including the lumen of the larger ducts. These lumina were filled with partly proliferated, degenerated, and desquamated cells. Round cells, leucocytes, and histiocytes infiltrated the epithelial layer and the granulation tissue. In the section from the periphery of the breast, there were within the fat tissue some leucocytic infiltration and abscess formation surrounded by many pseudo-xanthomacells intermingled with a few foreign body giant cells.

Diagnosis: Mastitis obliterans.

A second case coming under our observation is as follows.

A colored woman, aged 36 years, had always been in good health. She had had three pregnancies 18, 16, and 9 years previously, respectively. She had nursed each baby from nine to twelve months. There was no history of previous breast trouble at any other time. Menstrual history was normal.

Four weeks before coming under observation, the patient noticed a lump in the right breast about the size of a hickory nut. She had never previously noticed anything in this breast. For several days prior to observing the mass, she began experiencing some darting pains in the breast. Examination revealed a hard, irregular mass in the upper inner quadrant of the right breast about the size of a hen's egg. The mass was attached to the skin about one inch from the nipple but the breast itself was freely movable with no deep attachment of the tumor mass. A small amount of whitish yellow, milky looking fluid was expressed on palpation from the nipple. Temperature was normal, and the Wassermann blood reports were negative. Malignancy of the right breast was suspected and the breast was removed.

*Pathologic Report* (No. 17,912).—Clinical Diagnosis: Malignancy of right breast.

*Gross Description:* A hard fibrous mass about the size of a hen egg was found The mass was infiltrated with something resembling milk pockets.

*Gross Examination:* The piece of breast tissue 4 by 2.5 by 2 cm. consisted of fat and whitish glandular tissue which showed, upon cross section, a number of fine ducts with yellowish walls and small yellow geographical areas within the tissue.

*Microscopic Examination:* The breast showed ducts lined by granulation tissue, sometimes covered by irregularly grown epithelial cells. The granulation tissue itself consisted of large fibroblasts which contained fat and showed light cytoplasm of slightly foamy appearance. There was a fair amount of neutrophilic infiltration within the granulation tissue which narrowed the lumen of the ducts. The surroundings showed marked lymphocytic infiltration and occasionally groups of plasma cells, but the latter were not the predominant feature.

The granulation tissue of the ducts contained giant cells in some places and the lumen of one duct showed desquamated cells which were vesicular, clear, and contained fat. Within the desquamated epithelial cells could be found raylike bodies which consisted of fatty acid crystals and the center of these occasionally contained cellular detritus.

## DISCUSSION

Mastitis obliterans as a pathologic entity is characterized by the two inseparable features expressed by its name. First, a truly inflammatory mastitis and second, an obliteration of the milk passages. The structures involved are the acini, the ductal, periductal, and interstitial tissues.

Infiltrative, proliferative, and hyperplastic changes are part of the pathology of the ducts. Obliteration of the ducts in itself is not characteristic of the disease and may be found in other noninflammatory or inflammatory diseases of the breast. The primary, senile atrophic occlusion of the milk passages is known,[3, 4, 8, 22] although it is doubted by some authors.[2, 21] In cystic diseases of the breast "peritubular halos" of the ducts were first described with drawings illustrating the obliterating ducts by von Saar.[23] They were observed in association with carcinoma, especially scirrhous carcinoma[2, 16, 21] and mesenchymal tumors.[21] In reviewing some of our breast cases, we find occasional obliteration not only in cystic disease but also in intraductal papilloma and carcinoma. We have gained the impression that often the obliterating process seems to occur distal to a mechanical obstruction by tumor or cyst. An example of inflammatory disease which may spread intraductly is tuber-

culosis.[14] We have recently observed such a case in which the milk passages were filled with specific granulation tissue.

In obliterating mastitis the occlusion of the ducts is likewise distinctly inflammatory, but the granulation tissue prevails in a radial arrangement while noninflammatory lesions show a concentric pattern. Progressive and degenerative changes of the epithelium take part in filling out the lumina. This is exemplified by a proliferation producing giant cells or groups of cells undergoing necrobiotic changes such as fatty degeneration and desquamation. Sometimes clusters of fatty acid crystals can be found which grossly resemble sulfur bodies. The basal membrane of the duct is often destroyed by granulation tissue and this, coupled with the aforementioned changes, will frequently give a picture which

Fig. 1.—Shows a large duct nearly obliterated by granulation tissue. There is desquamation of epithelial cells in the center of the duct.

simulates tuberculosis or even carcinoma. Interstitial changes are often found associated with the ductal lesions. Inflammation may produce neutrophilic, eosinophilic, lymphocytic, and plasmacellular infiltration. Damage to the fatty tissue leads to necrosis and there will also be present lipophagic elements, sometimes referred to as pseudoxanthoma cells, foreign body giant cells, and frequently fatty acid crystals. The great resemblance, clinically, of mastitis obliterans to carcinoma and lesions simulating cancer must be strongly emphasized in the differential diagnosis.

The recently described plasma cell mastitis deserves a more extensive discussion. Although the latter term was first used by Ewing,[9, 10] he has never claimed priority of authorship, which he attributes to Adair. Adair first published a series of cases[1, 5] under the title of plasma cell mastitis and his reports were followed by contributions from Miller[18] and Rodman and Ingelby.[19]

If one compares the description and photomicrographs of the two diseases, there will be observed a very great similarity. Clinically, the gross symptoms and findings are identical. Ewing[10] states that in plasma cell mastitis "the main gross anatomical feature is the presence of many greatly thickened ducts," but his microscopic description would

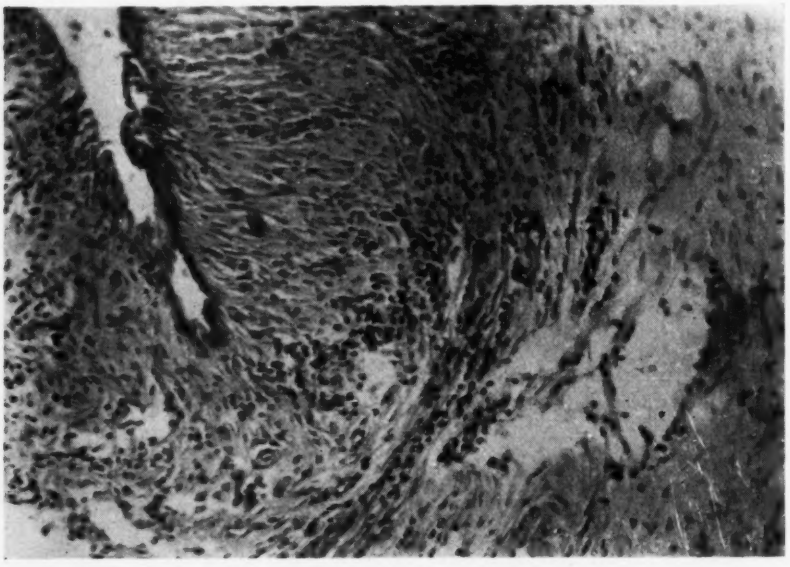

Fig. 2.—Shows a corner of a larger duct. The infiltrating cells are mostly lymphocytes, but this is one of the regions where some plasma cells are found.

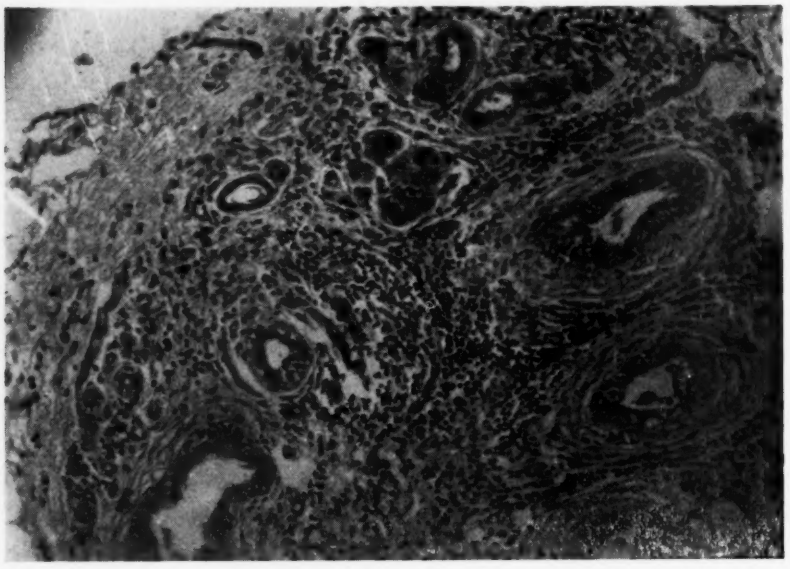

Fig. 3.—Shows smaller ducts, likewise with proliferation of the subepithelial connective tissue and marked proliferation of the epithelium. The infiltration is merely lymphocytic; plasma cells are absent.

be mainly a repetition of the features of mastitis obliterans herein described. The difference remaining between the two diseases is possibly a more pronounced occlusion of the ducts by granulation tissue in obliterating mastitis in contrast to a marked infiltration of plasma cells. This led Ewing, Adair, and Rodman to name the picture plasma cell mastitis. We would like to record the opinion here that plasma cells as a feature of the picture are not of sufficient importance to establish a new entity of mastitis. So far as we know they are not pathognomonic of any one lesion. Plasma cells are merely a cellular expression of the

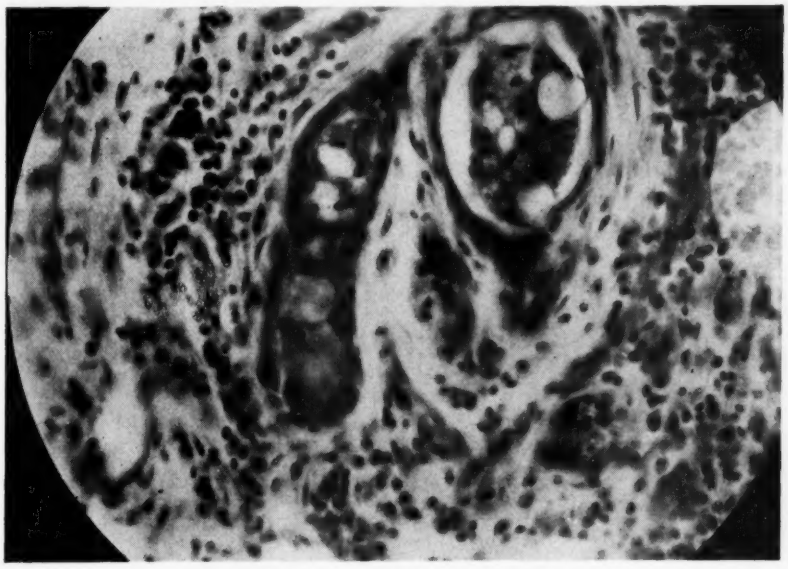

Fig. 4.—Shows a small duct under high power. The epithelial tissue is in marked proliferation, atypical, with giant cells, and in vacuolar degeneration. There is budding of the ducts. The infiltration is lymphocytic with some plasma cells, and shows about the maximum of plasma cells found in any of the slides.

chronicity of an inflammation. There are a great number of other cells present in the published photomicrographs of plasma cell mastitis such as neutrophiles, eosinophiles, lymphocytes, and pseudoxanthoma cells. Generally we classify inflammatory lesions in conformity with their etiology, localization, stage, and certain complex features but not according to the predominant types of cells found. We recognize obliterating inflammations, such as bronchitis and phlebitis, but to use the term plasma cell inflammation is definitely a generalization even though these cells may often predominate in certain lesions, such as are found in the Fallopian tubes or the nasal mucosa. Gross cancer-simulating features have led to the adoption of the name plasma cell mastitis to define both a clinical and pathologic entity. These cancer-simulating features do not depend on the predominance of the plasma cell. The marked proliferation of the connective tissue, especially the subepithelial connective tissue, is the reason for the cancerous appearance on clinical exam-

ination. The proliferation of the subepithelial connective tissue, the obstruction of the ducts by the latter, and the irregular proliferation of the ductal epithelium are the most striking features. Plasma cells are nothing but the expression of a chronic inflammation of long duration. They are not pathognomonic of anything. Recently we have observed a massive plasma cell exudation of the periductal tissue surrounding an old sinus tract of the breast, yet none of the cancer-simulating features of so-called plasma cell mastitis were present. These

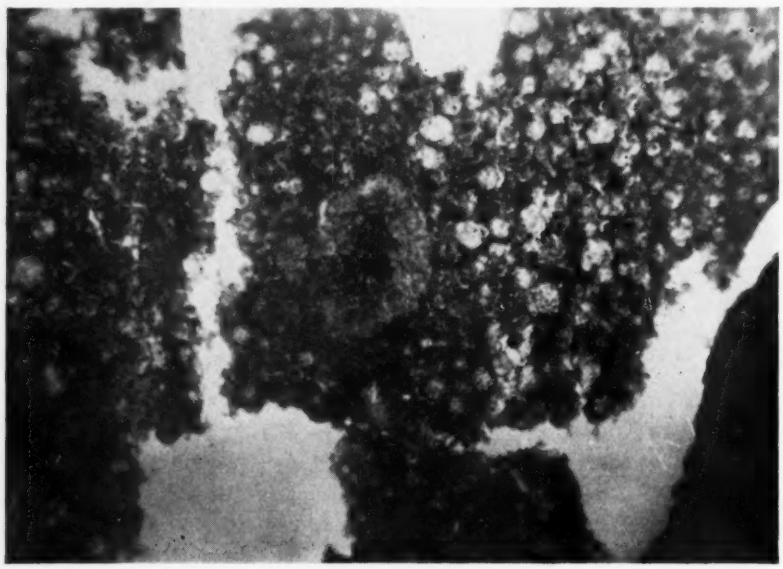

Fig. 5.—A cluster of fatty acid crystals in the midst of debris filling a duct.

cancer-simulating features are produced by the contraction of inflammatory granulation tissue and the irregular retraction mass consists of thickened ducts and inflammatory cells of all types independent of the presence of more or less plasma cells. Thus we believe that the name, plasma cell mastitis, is superfluous and that the well-known terms of subacute and chronic (inflammatory) mastitis are sufficient with their old subdivision according to the main localization, interstitial and ductal types. The microscopic picture of the ductal types may show a prevalence of neutrophiles, eosinophiles, lymphocytes, and plasma cells without any recognized change in the clinical picture or in the gross specimen. If the lesion reaches the stage of tortuous, thickened ducts, easily recognized on cut surface, the old term of obliterating mastitis seems justified. Although we deem the new name of plasma cell mastitis superfluous, we think that Adair, Rodman, and others deserve much credit for emphasizing the difficulties in distinguishing the lesion under discussion from malignancy and other inflammatory lesions.

From the standpoint of clinical differential diagnosis, obliterating mastitis belongs to the group of lesions which may be confused with

cancer. Principally, these lesions are cystic disease of the breast, subacute and chronic mastitis, lactation mastitis, galactocele, traumatic fat tissue necrosis, tuberculosis, actinomycosis, and syphilis of the breast. The features of these diseases have all been discussed in a number of excellent and recent publications.[1, 5, 6, 7, 17, 18] Obliterating mastitis simulates cancer in many respects. Usually there is a lump generally located in the neighborhood of the areolar region. This mass is adherent to the skin and may be reddened as in inflammatory carcinoma. Often the nipple is retracted. The axillary glands may be enlarged. On the other hand, if there is a history of previous inflammation, if the mass and lymph nodes are tender and painful, if the thickened ducts can be felt in the mass, and especially if yellowish creamy material can be expressed or sucked from the nipple, one should think of mastitis obliterans.

SUMMARY

Two cases of mastitis obliterans, a lesion simulating cancer, are described and its realtion to so-called plasma cell mastitis is discussed.

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# THE USE OF INTRAVENOUS AMMONIUM CHLORIDE IN THE TREATMENT OF ALKALOSIS

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THE need for a more effective parenteral method of correcting alkalosis has arisen with increasing frequency during recent years. Hartman and Senn[1] pointed out the usefulness of an intravenous solution of sodium lactate for overcoming acidosis, but no parenteral preparation has been generally available for the correction of alkalosis. In a limited number of cases, intravenous ammonium chloride has proved to be highly effective in combating alkalosis.

Undoubtedly, the use of continuous suction drainage of the stomach, especially in the preoperative preparation of patients with pyloric obstruction, has been responsible for most of the cases of severe alkalosis. The use of suction drainage in patients with pyloric obstruction, as advocated by Graham,[2] is a procedure which we believe has reduced the morbidity and mortality of operative procedures on the stomach and duodenum. Graham has recommended not only that the stomach be washed out, but that it be kept clean and empty for a number of days before operation.

Patients with pyloric obstruction, when they are first hospitalized, commonly have a considerable degree of alkalosis from vomiting alone, since the vomitus contains more anions (especially chloride) than it does cations other than hydrogen. Suction drainage further accentuates the alkalosis. Some of these patients lose enormous quantities of gastric juice. The volume of gastric drainage may amount to over 6 liters per day. When such exaggerated losses occur, they tend to accelerate the development of alkalosis and increase its severity.

For some years the medical profession followed the view advanced by Gamble and Ross[3] that if the body was supplied with sufficient physiologic saline solution and if ketosis was prevented, the electrolyte pattern of the plasma would be adjusted satisfactorily by the kidneys. It is well known that infants and adults ill with pneumonia are frequently unable to dispose of surplus sodium.[4] Similar limitations of sodium excretion were found to apply to certain postoperative patients by Jones and Eaton.[5]

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Gambill and Sharpe,[6] in a discussion of alkalosis and gastric tetany, dismissed the use of ammonium chloride on the findings of Gamble and Ross.[3] Gamble and Ross found that rabbits with complete pyloric obstruction lost not only chlorides but also considerable amounts of base in the form of sodium. In their animals the total base as well as the chlorides was depleted. Their experiments showed that saline solution kept the animals alive while ammonium chloride did not keep them alive although it did overcome the alkalosis.

In the patient with excessive gastric drainage, replacement of the drainage fluid by sodium chloride solutions in quantities calculated to keep the patient in positive water and electrolyte balance does not always effectively combat alkalosis. The patients reported in this series all received fluid and sodium chloride in amounts calculated to restore their plasma electrolyte patterns. In five of the instances the total serum base was determined by chemical analysis. In the remaining cases the total base was approximated from the serum protein level, $CO_2$ value, and serum chloride level according to the method of Elkinton, Gilmore, and Wolff.[7] The total serum base in each of the reported cases was above the lower limits of the normal accepted range of total serum base. It is in this type of patient, namely, the patient with severe alkalosis, who has been treated with ample fluid and sodium chloride, that we believe the intravenous injection of ammonium chloride is at times justified. Alkalosis not only may produce tetany and convulsions but it may produce serious renal damage, the alkalosis nephrosis described by Nicol[8] and others. It, therefore, seems wise to overcome the alkalosis and to restore electrolyte balance of the blood as promptly as possible. Intravenous ammonium chloride is not only effective but it is also prompt in its action.

Ammonium chloride has long been employed by the oral route to acidify the urine. It has been used to advantage occasionally by the same route to overcome alkalosis, but the oral route is not available in the group of patients in which the tendency to alkalosis is greatest, those who have pyloric obstruction. The rectal route in our experience proved to be of only limited value. Some reduction in serum $CO_2$ was obtained but the change was slow (Table I).

The results of the intravenous administration of ammonium chloride twelve times in seven patients on surgical service B at the hospital of the University of Pennsylvania, are shown in Table I. In most instances the response was quite uniform. The figures obtained indicate that for an adult of 150 pounds, 1 Gm. of intravenous ammonium chloride will reduce the serum $CO_2$ by an average of 1.1 volumes per cent. On the basis of this experience the dose may be calculated according to the instructions in Table II. These findings indicate a wide distribution of the solute in body water.

TABLE I

| PATIENT | DIAGNOSIS | AMT. OF $NH_4Cl$ SOL. | | $CO_2$ VOL. % | | VOL. % $CO_2$ DECREASE PER GM. $NH_4Cl$† |
|---|---|---|---|---|---|---|
| | | (C.C.) | (%) | BEFORE | AFTER | |
| J. M. | Perf. gastric ulcer | 200 | 2 | 72 | 67 | 1.3 |
| J. E. M. | Perf. ca. of sigmoid with peritonitis | 200<br>*200 | 2<br>2 | 75 | 62 | 1.2 |
| A. H. | Chronic peptic ulcer with stenosis, avitaminosis | 750<br>*500 | 2<br>2 | 152 | 112 | 1.1 |
| A. H. | Chronic peptic ulcer with stenosis, avitaminosis | 700 | 2 | 113 | 85 | 0.9 |
| A. H. | Chronic peptic ulcer with stenosis, avitaminosis | 250 | 1.7 | 76 | - | - |
| A. H. | Chronic peptic ulcer with stenosis, avitaminosis | 650 | 2 | 84 | 62 | 1.1 |
| H. D. | Chronic peptic ulcer with stenosis | 1,000 | 2 | 87 | 51 | 1.2 |
| S. H. | Perf. appendix with peritonitis | 1,000 | 2 | 80 | 65 | 1.1 |
| T. B. | Bleeding peptic ulcer, hypoproteinemia | 750 | 2 | 87 | 75 | 0.9 |
| T. B. | Bleeding peptic ulcer, hypoproteinemia | 500 | 2 | 77 | - | - |
| T. B. | Bleeding peptic ulcer, hypoproteinemia | 1,000 | 2 | 87 | 76 | 0.6 |
| M. M. | Ca. of pancreas | 1,000 | 2 | 117 | 80 | 1.5 |
| | Average | | | | | 1.1 |

*These patients received part of this $NH_4Cl$ by rectum.
†These figures have been calculated for a body weight of 150 pounds.

TABLE II

DOSAGE OF AMMONIUM CHLORIDE

| TO REDUCE THE SERUM $CO_2$ | ALLOW |
|---|---|
| One volume per cent | 16 mg. per kilogram of body weight<br>or<br>7.3 mg. per pound of body weight |
| One milliequivalent | 36 mg. per kilogram of body weight<br>or<br>16 mg. per pound of body weight |

Two per cent solutions of ammonium chloride were prepared by dissolving 20 Gm. of ammonium chloride in a liter of water, 0.9 per cent sodium chloride solution, or 5 per cent dextrose solution. In most instances the solution was brought to boiling just before the ammonium chloride was added and then allowed to cool slowly. It was then used as soon as it had cooled sufficiently.

We have, however, given 2 per cent ammonium chloride with 0.9 per cent sodium chloride without reaction after autoclaving at 15 pounds pressure for twenty minutes. If 5 per cent glucose is present a marked brownish color develops suggesting caramelization. Such solutions have not been used.

The rate of administration has varied with the exigencies of the case but usually it was not greater than 1000 c.c. in two hours. It is pos-

sible that slower rates of administration and more dilute solutions will prove to be of advantage except when tetany has appeared.

No serious reactions have been encountered but three transient reactions have occurred. Two of these patients complained of a sensation of lights flashing before their eyes and the third patient had a chill lasting three minutes, with a rise of temperature to 102° F. It may be of interest that the two patients who experienced the scintillating scotoma received a solution of ammonium chloride in distilled water with no other solute, whereas the patients who had no reactions received ammonium chloride in solutions of either sodium chloride or glucose.

## CONCLUSIONS

Severe alkalosis may result from continuous gastric suction, especially in patients with pyloric obstruction.

Ammonium chloride solution was administered intravenously to seven patients with alkalosis without evident harm.

It was effective in rapidly lowering the serum $CO_2$ at the rate of approximately one volume per cent for each gram administered to adults of medium size and weight.

Sufficient evidence has not accumulated to determine the safety of this method of administration, but it appears sufficiently safe to warrant its use in severe alkalosis that cannot be corrected by the administration of salt and fluids promptly enough to avert the danger of renal changes.

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# THE ROLE OF SURGERY IN THE TREATMENT OF MALIGNANT SKIN TUMORS

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CANCER of the skin is the most common malignant tumor affecting the human body, and, in most of its manifestations, the most easily curable. The average early cancer can be eradicated by any of several destructive methods, surgical excision, the selectively destructive roentgen or gamma rays, electrodesiccation, or by zinc chlorine or other pastes. Irradiation and surgery are now the most frequently used, irradiation being the more universally employed. Both surgical and radiation methods have special advantages in particular types of skin cancer, but neither is capable of being employed universally to the best advantage. The purpose of this communication is to attempt a definition of the phases of skin cancer best suited to surgical treatment. It must be realized that there are many borderline situations in which indications for either surgery or radiation may overlap, and in such a situation the therapist is justified in using either method with which he is most familiar and skillful.

## PROPHYLAXIS

Prophylactic treatment of precancerous lesions is concerned mainly with the keratoses and dyskeratoses, and is principally a radiation problem. These lesions occur, as a rule, late in life and are usually found on the face, neck, and backs of the hands. However, surgery is definitely the method of choice for the following two classes of lesions.

*Benign Neuronevus.*—The common mole, or benign neuronevus, when in a location exposed to constant irritation, should be completely excised surgically. Probably all moles on the feet should be removed, as they are particularly prone to malignant transformation. Other dangerous locations are the belt line, the shoulders, the neck (where a collar may rub the lesion), and the neck or face in males where shaving may cause repeated slight trauma. It cannot be too strongly emphasized that, when the decision is made to remove them, these lesions should be completely excised. Tampering with them by electrodesiccation or incomplete removal is inviting serous trouble. Radiation is, of course, entirely useless.

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*Postradiation Keratosis.*—Postradiation atrophy of the skin with beginning keratosis is a precancerous lesion which should be excised and replaced by a full thickness or thick split-skin graft. The younger the patient the more important is this therapy. For obvious reasons the majority of such lesions are seen as late results of radiation dermatitis caused by accidental exposure or from x-ray therapy given to benign lesions. The majority of precancerous late radiation effects are from unfiltered or lightly filtered low-voltage x-rays. However, the much "harder" gamma rays from radium or radon may also produce this result. Radiation sclerosis of the skin from accidental exposure is usually seen today on the fingers and hands of radiologists, orthopedists, or other surgeons accustomed to setting fractures under the fluoroscope. Those lesions resulting from treatment of benign lesions are commonly seen about the face and chin of women who received epilation doses of low-voltage x-ray for hirsutism. Enthusiastic treatment of chronic dermatologic conditions with x-ray also furnishes a number of such patients (Fig. 1). In recent years older children and adolescents who were treated by radium in infancy for hemangiomas are also being seen with precancerous radiation dermatoses. These latter patients constitute an imperative indication for excision and skin graft as prophylaxis against cancer, as eventual malignant transformation of such areas is almost inevitable, due to the patient's greater life expectancy.

## SURGERY IN SPECIFIC TYPES OF SKIN CANCER

*Melanoma.*—Malignant melanoma when still operable is an absolute indication for surgical treatment. These tumors are almost all completely resistant to radiation, and radical surgery is the only method of therapy available. These lesions should be excised widely and deeply without regard to subsequent cosmetic effect. The underlying fascia should always be included in such a removal. If, as occasionally happens, a supposedly benign nevus is excised and turns out to be melanoma, an immediate re-excision should be done if there is any doubt about the adequacy of the original surgery. Malignant melanoma usually metastasizes first to its regional nodes, except in the hopeless fulminating cases where explosive metastases seem to occur simultaneously throughout the body. In operable melanoma the regional nodes may be handled in one of three ways. If the primary lesion is close enough to the regional nodes, these may be removed with the primary as an en bloc dissection, an operation for which the term "excision and dissection, in continuity" has been coined (Fig. 2). This conforms to the ideal concept of extirpative cancer surgery, a principle which the present day radical mastectomy exemplifies. In such an operation the primary lesion, the majority of the direct lymphatic pathways, and the regional nodes are removed in one piece, with all contained tumor cells

and emboli. Such an operation is ideal whether or not the regional nodes are clinically involved. If the primary lesion is too far away for such a procedure the nodes should be removed at the same time or shortly thereafter if they obviously contain metastatic tumor. If the nodes are not clinically involved the best practice today is to wait six to eight weeks after the primary is excised and then do a radical dissection of the

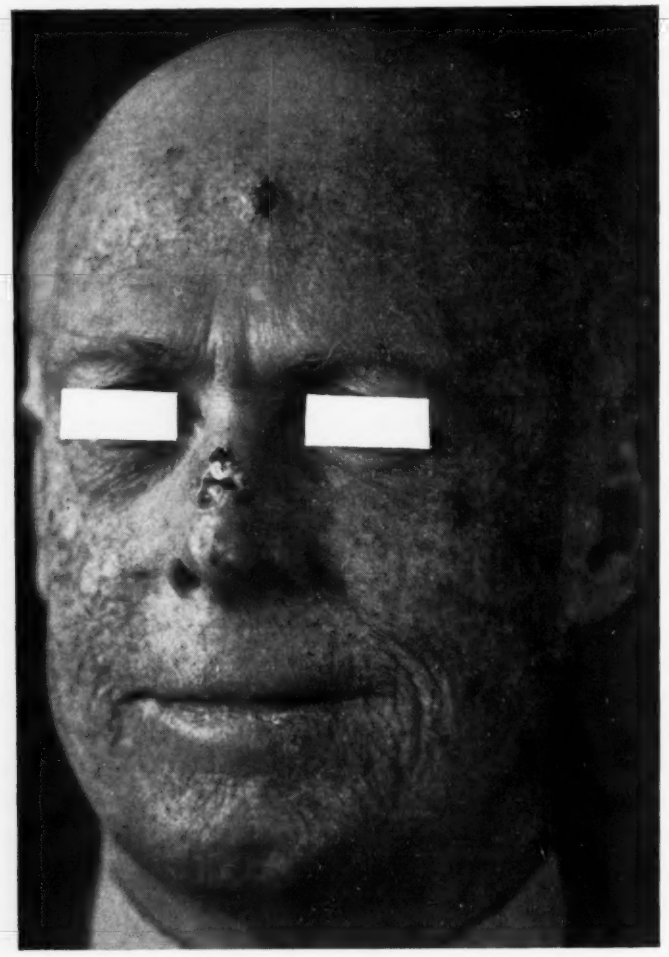

Fig. 1.—Late radiation effect on skin from low-voltage x-ray administered during adolescence for Acne.

regional nodes (Fig. 3). The theoretical advantage of this maneuver is that it allows tumor cells already in the lymphatics to reach the regional node filter. That this is more than a theoretical consideration is shown by those patients who develop numerous minute skin metastases along the lymphatic pathways when uninvolved nodes have been removed separately but simultaneously with the primary lesion. In contrast to the problem of node involvement from squamous cancer,

it is believed justifiable to perform prophylactic node dissections in patients with melanomas. Adequate statistics are not available to show the percentage, but it is the general opinion that metastases from

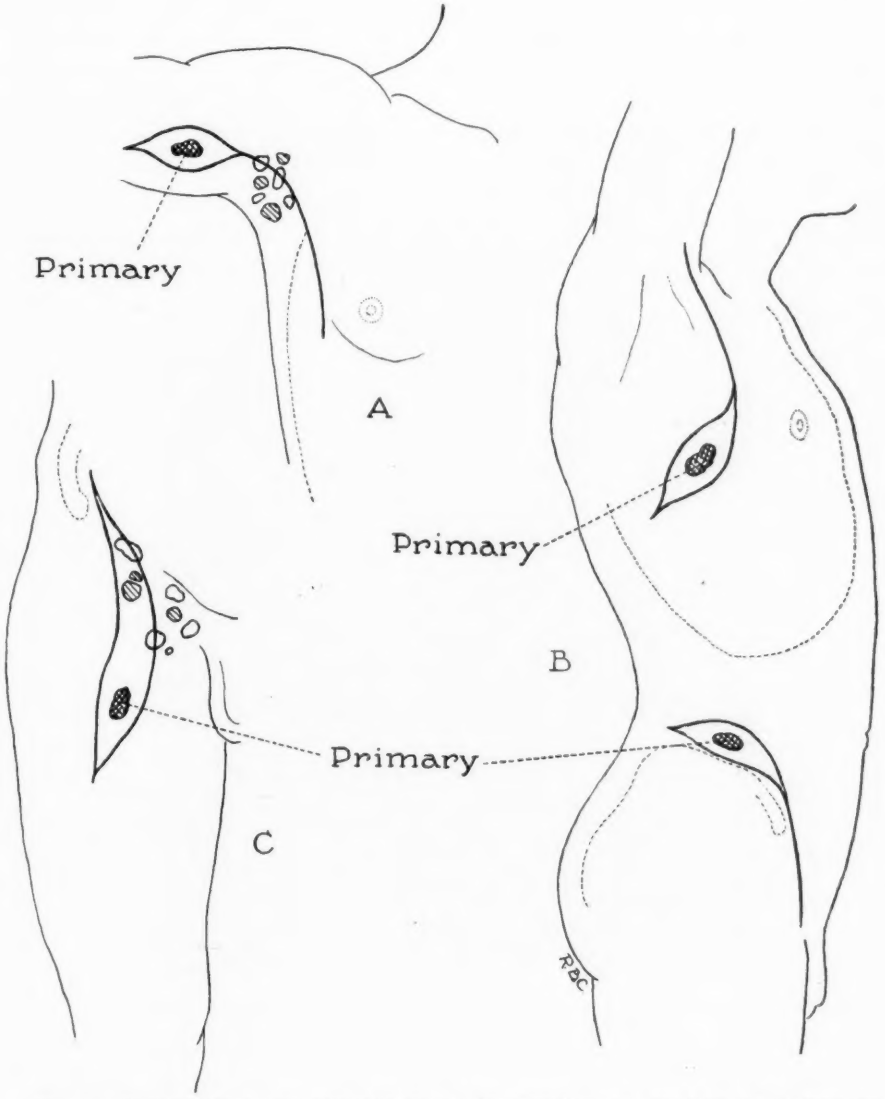


Fig. 2.—Illustrating a few possibilities of the operation of "excision and dissection in continuity." In these diagrams the primary lesion is so situated that it can be removed, along with the regional nodes and their intervening lymphatics, with one continuous incision. Such an operation may have an infinite number of anatomic variations and is suitable whether or not the regional nodes contain metastatic disease.

melanoma are found much more often when dissections for clinically uninvolved nodes are done, than is the case with squamous lesions.

*Residual or Recurrent Disease.*—In spite of the radiocurability of most squamous and basal-cell cancers of the skin, the occasional radiation failure presents a perplexing problem. Residual disease, that is, viable

cancer remaining in an area that has been treated to the limit of tissue tolerance, presents two alternatives, either surgical removal or further irradiation with resultant radionecrosis. This last course defeats the original indication for the use of radiation, and in most instances should not be followed (Figs. 4, 5, and 6). It should be noted that the diagnosis of residual disease must not be made for some time after treatment is finished, as continued regression of the tumor may take place for eight to twelve weeks after the acute reaction in normal tissues has occurred

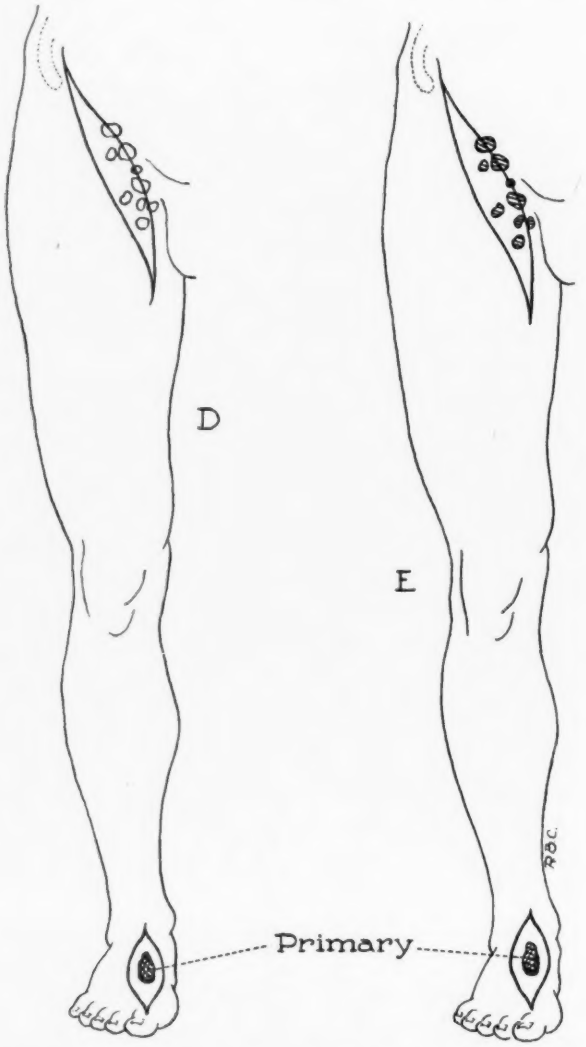


Fig. 3.—Illustrates the problem presented when the primary lesion is too far removed from its regional nodes to remove them and the intervening lymphatics through one incision. *D* illustrates the situation when the nodes are not clinically involved. Here the nodes should be removed by radical dissection six to eight weeks after the primary is excised, the time interval allowing the lymphatics to empty any tumor cells into the regional node filter. *E* illustrates the situation when the regional nodes obviously contain metastatic disease. These must be removed as soon as possible and usually simultaneously with the excision of the primary lesion. Here the patient and surgeon must sacrifice the possibility of further lymphatic metastases for the expediency of removing those already present.

and healed. Once the existence of residual disease has been established, however, recourse to surgery is usually the wisest choice. A wide excision of the entire area should be done and the defect repaired with a full thickness or a thick split-skin graft. Recurrent disease is actively growing cancer, arising, of course, in a focus of unrecognized residual disease. It is simply a further stage of the other, and should be treated in the same way and for the same reasons. The indication for the use of surgery in these conditions is a relative one, depending largely on individual circumstances. For a small focus of residual disease situated well below the skin surface, interstitial radiation in the form of gold radon seeds may often complete the tumor regression. In general, however, surgical excision with immediate or delayed grafting is preferable.

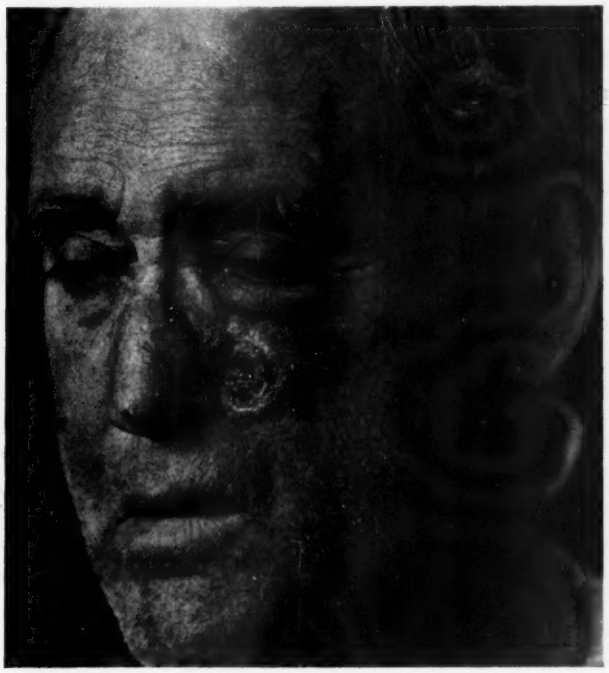

Fig. 4.—Illustrates a patient with squamous carcinoma inadequately treated by irradiation. The tissues will not now tolerate a complete cancericidal dose, which is necessarily more than that originally given, and the problem now is one of a mutilating surgical procedure along with excision of the neck metastases.

*Radiation Cancer.*—Carcinoma arising in skin that is atrophic and telangiectatic as a late result of radiation is almost invariably a surgical problem. In the first place, such a tumor is usually squamous carcinoma, and as such is relatively radioresistant, requiring a high dosage to kill it. In the second place, the tumor bed and surrounding tissues, already damaged by radiation, will not tolerate cancericidal doses of roentgen or gamma rays. In the third place, these lesions are frequently located on the fingers and hands, areas which tolerate radiation poorly because of the close proximity of bone. If a biopsy of a radiation cancer shows

the tumor to be a spindle-cell variant of squamous carcinoma, the indication for surgery is absolute. Martin and Stewart[1] state that spindle-cell epidermoid carcinoma is practically incurable by radiation, and such a tumor should always be attacked surgically. Spindle-cell carcinoma may be found in radiation cancer, as a metaplastic phase of radiated and recurrent squamous carcinoma, or occasionally as an ex-

Fig. 5.

Figs. 5 and 6.—Illustrate the preoperative and immediate postoperative condition of a patient who had been treated for twelve years by repeated inadequate doses of radium. The outer table of the skull and the roof of the frontal sinus had to be removed. Actively growing basal-cell carcinoma was invading the orbit.

pression of the carcinogenic effect following chronic arsenic poisoning or long-standing psoriasis. Whenever it is encountered it should be treated by surgical methods if feasible and not by radiation.

*Burn Scar Cancer.*—Epidermoid carcinoma rising in old burn scars presents a specific problem quite distinct from the ordinary occurrence of skin cancer. It originates on a fibrotic, relatively avascular tissue bed whose lymphatics are few in number and functionally distorted. The tumor cells themselves ordinarily are so highly differentiated that they may closely resemble normal mature squamous epithelial cells, and thus histologically would be classified as radioresistant. Burn scar cancer

usually is indolent and tends to metastasize late, but it is very stubborn in response to treatment because it tends to recur locally. Patients with these tumors frequently give a history of repeated excisions with recurrence in adjacent areas. This is thought to be a result of the disruption of lymphatic pathways in the scarred tumor bed, with a consequent atypical metastatic pattern. Such a tumor is a surgical problem because it not only requires a high dosage of radiation to sterilize it, but also because it grows in a tumor bed of avascular scar tissue that will not tolerate cancericidal doses of the order needed. When excision of such a lesion is done, it must be carried much wider than is necessary

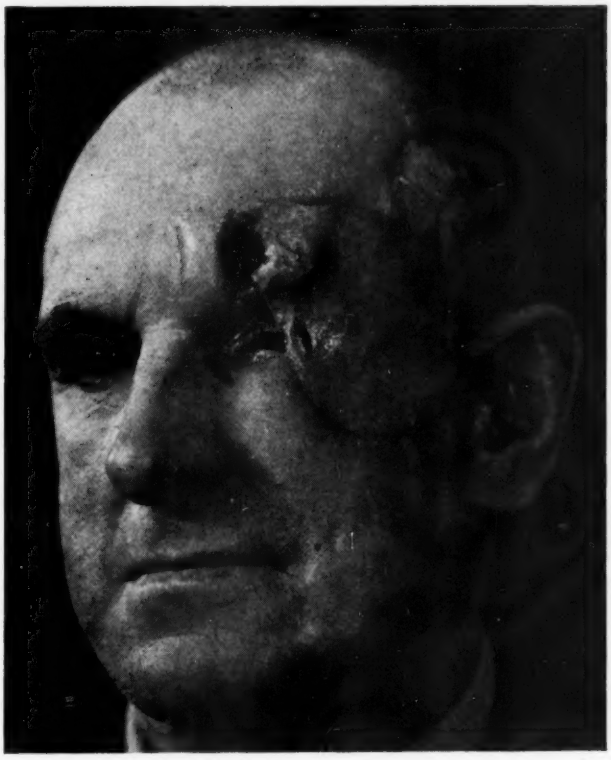

Fig. 6.—For legend see opposite page.

for the usual skin cancer because of this tendency of burn scar lesions to recur in nearby sites. Ideally, the entire scar and tumor should be excised and the area covered by a split-skin graft. This is, of course, frequently impossible because of the size of the area involved by many burn scars. The entire thickness, at least, of the scar should be removed under the lines of incision. The extent of excision required in these lesions is another contraindication to radiation therapy, as a cancericidal dose of x-ray could not be delivered over such an area, even through normal skin.

CONSIDERATIONS OF ANATOMIC LOCATION AND EXTENT

*Scalp.*—Most small or medium-sized squamous and basal-cell cancers of the scalp are best treated by radiation. However, the occasional large and deeply ulcerating lesion is best treated by wide surgical excision and immediate skin graft. This is because destruction of such a tumor by radiation may expose the underlying bone which has been partially devitalized by the radiation. Severe osteomyelitis of the skull may en-

Fig. 7.—Patient with sequestration of the skull following intensive irradiation of a large, ulcerating basal-cell carcinoma of the scalp. The floor of the defect is the exposed dura.

sue, or, at the least, osteoradionecrosis with sequestration of the irradiated area (Fig. 7). Exposure by surgery of healthy, nonirradiated bone is not necessarily serious and can easily be repaired by skin grafting. If the galea or periosteum is removed an immediate thin split-skin graft may be made to grow on the exposed bone without waiting for drilling and formation of granulations. It is certainly worth while attempting such a procedure as the chance of loss of such a graft is much

less of a problem to the patient than the three to six weeks required by the maneuver of drilling and waiting for granulations. If the primary graft takes, the procedure is finished. If it does not the patient has lost nothing but a few days, as the donor site of a split-skin graft restores itself very completely.

*Ears.*—Cancer of the skin of the auricle is as easily cured by radiation as skin cancer anywhere else, but because of the proximity of the cartilage to the surface, ulceration and nonhealing are frequent occurrences. Primary excision of these lesions, with or without a "V" removal of the cartilage, usually results in a better cosmetic effect in spite of the surgical defect. Long-continued ulceration following irradiation, or eventual sloughing, are far more trying to a patient than simple excision and primary healing of healthy tissues. Radionecrosis, furthermore, often requires more extensive surgical procedures than would have been necessary by surgical excision in the first place. The larger the lesion, or the deeper it extends, the more imperative is the indication for surgical attack. Many radiologists refuse to treat such lesions after experiences with chronic perichondritis or chondronecrosis.

*Midline Lesions.*—Cancer of the skin occurring in the midline of the body is better treated by surgery than radiation, the reason being that the blood supply is least in this area. Tissue recovery following irradiation is directly dependent on the blood supply to the region treated. These considerations do not apply to the face, scalp, or perineum, where the blood supply is excellent, and therefore lesions falling in this class are quite rare.

*Cancer in Skin Adjacent to Bone.*—Carcinoma of skin overlying a bony prominence is better treated by surgery than by irradiation for two reasons: first, the blood supply to the integument is usually less in such areas; second, bone is easily damaged by radiation, and, being close to the skin surface, receives a high tissue dosage when radiation therapy is given.[2] These conditions tend to delay healing, and lead to late radionecrosis and breakdown (Figs. 8 and 9). Such vulnerable areas of skin are found on the hands and feet, over the malleoli, and over the anterior aspects of the tibiae. It has long been known that irradiation of the fingers or the dorsum of the foot is a dangerous practice, and this is almost equally true of the metacarpal area. The disastrous late results of accidental irradiation occurring in the hands of radiologists and surgeons are effects of comparatively low doses of radiation. The full cancericidal doses required to sterilize the squamous carcinomas found in these regions are even more destructive. In many patients so treated, surgical procedures necessitated by the late results of radiation would be simpler both to the surgeon and the patient if they had been done in the first place.

*Perineum.*—Cancers of the skin of the anus, vulva, scrotum, or penis are more suitable to surgical treatment than irradiation, because the skin

of these regions tolerates radiation poorly. This skin is more moist than other areas in the body and maceration occurs early during radiation therapy, thus making the reactions more intense, and thereby limiting the total dose that can be given. For the same reasons the late effects of radiation are far more distressing to the patient than is usual for

Fig. 8.

Fig. 9.

Figs. 8 and 9.—Radionecrosis through the hand with gangrene of the fingers following irradiation of a carcinoma of the palm eight years previously. There is no tumor present in the lesion.

drier regions. Ulceration and infection occur more commonly, and a patient with radiation dermatitis about the perineum may be permanently miserable. Lesions of the vulva or scrotum lend themselves readily to surgery because of the ease of repair in redundant tissues, and because of excellent blood supply. The scrotum, furthermore, is a poor site for irradiation from the standpoint of damage to the contained testicles. Cancer of the skin about the anus deserves special consideration, because, if surgical treatment requires a permanent colostomy and posterior resection, or even rectal incontinence, the disadvantages of radiation must be balanced against these factors. Such a situation, however should not influence the physician to attempt the impossible with radiation. Cancer of the penis is almost invariably best treated by surgical measures. In this connection it should be noted that circumcision in infancy or childhood is practically 100 per cent prophylactic protection against the later development of cancer in this organ.[3]

*Skin Cancer Invading Bone or Cartilage.*—It is practically impossible to cure squamous or basal-cell cancer invading bone or cartilage by irradiation. Such lesions on the extremities, when very large in extent, require amputation. Pack and Livingston[4] list the indications for amputation in patients with extensive skin cancer of the extremities as follows: (1) hemorrhage caused by erosion of a large vessel; (2) when the interior of a large articulation is exposed; (3) when the cancer has invaded so deeply and become so adherent that excision is impossible; (4) when large areas of bone are exposed, resulting in necrosis; (5) when uncontrollable suppuration of the wound is complicated by fever and toxemia; (6) when the functional result, even after a presumptive local cure, would be unsatisfactory, the limb becoming an encumbrance.

## CANCER COMPLICATING SPECIFIC SKIN DISEASES

Squamous and sometimes basal-cell carcinoma occurs as a complication or result of certain skin diseases, notably in xeroderma pigmentosa, acrodermatitis chronica atrophicans, and rarely as a late result of lupus vulgaris and lupus erythematosis. Patients with xeroderma pigmentosa usually present impossible therapeutic problems, and they commonly die in early adult life of multiple skin cancers. These tumors are a result of the action of actinic rays on the damaged skin, and as such are not suitable for treatment by further radiation. They therefore are surgical problems, although only in a palliative way. Cancer arising in lesions of acrodermatitis chronica atrophicans should be treated by surgical excision because the atrophic skin will not tolerate cancericidal doses of radiation. The same considerations apply to cancer arising in skin which has been the site of lupus vulgaris or erythematosis, although to a lesser extent. Decision as to treatment in this latter situation depends upon the degree of skin damage resulting from the previous disease.

## REGIONAL NODE METASTASES

In one sense the treatment of metastatic nodes in patients with skin cancer is of more concern than treatment of the primary lesion. In the first place, skin cancer usually kills by its metastases rather than by the local effect of the primary lesion, differing in this respect from some other tumors, such as untreated cancer of the larynx or esophagus. In the second place, most skin cancers can be fairly easily cured at the primary site by any of several means, as stated before.

The question of the treatment of regional node metastases from squamous cancer has been repeatedly discussed from many angles. The majority of the opinions today seems agreed on the following premises: that prophylactic dissection of regional nodes is not only unnecessary, but may actually be harmful; that the treatment of operable metastatic cancer in nodes should be surgical and not by radiation. Prophylactic regional node dissection, i.e., where metastasis is not demonstrable, has been shown conclusively by Martin[5] and Duffy[6] to be a waste of time in most patients with squamous carcinoma of the lip, mouth, and pharynx. The same reasoning and conclusions are equally applicable to squamous carcinoma of the skin. That prophylactic dissection may be harmful is illustrated by those patients who develop inaccessible metastases, because of diverted lymphatic flow, sometime after node dissection. The regional lymph nodes act as a temporary filter for tumor cells loose in the tissue lymphatics, and they will hold them in check until the tumor destroys the node and breaks through the capsule. When a node becomes blocked by tumor cells, local diversion of lymphatic flow occurs, and thus successive adjacent nodes become involved, by collateral flow. This is why it is futile to do a local excision of a solitary involved node. Whenever surgical extirpation of a regional metastatic node is done, the operation must be radical, removing the entire node bearing area by an en bloc dissection.

The use of radiation in the treatment of node metastases from skin cancer either should be confined to palliative therapy for late and inoperable lesions, or should be used as a delaying action, as it were, in holding in check cancer in regional nodes while the primary lesion is either being definitively treated by radiation or prepared for excision. This latter course is only an expediency to delay growth of metastases until regional dissection can be done. Metastatic squamous cancer in nodes can be cured occasionally by roentgen or gamma radiation, but in too small a percentage of cases for this form of therapy to be seriously considered as an equal alternative to radical regional node dissection in operable cases.

The types of neck dissection for cervical metastatic cancer have been described recently by Martin,[5] and the operation of radical groin dissection has been redefined and elaborated by Pack and Rekers.[7] For dis-

section of node metastases from skin cancer in general, two conditions are necessary: one, the primary lesion must be controlled, or be removed simultaneously; two, the nodes must be operable. Quixotic attempts at removal of huge masses may be useful from a palliative standpoint, but they are not curative. Bilateral metastases to the neck, groins, or axillae from midline skin lesions are not contraindications to dissection if the lesions are operable. Bilateral dissections should be done when bilateral metastases are present, because nothing else affords the patient an equal chance in such a situation.

### SURGERY AS AN ADJUNCT

The use of surgery and radiation combined as complementary methods has little place in the treatment of skin cancer in general. It is no more reasonable to use "postoperative irradiation" after surgical removal of a malignant skin tumor than it would be to do a little surgery after adequate irradiation of such a lesion. Surgery may be employed to advantage, however, in the everting or polypoid lesions, as an adjunct to irradiation. Radiation may be used much more effectively in such situations if the main bulk of the tumor mass is first removed surgically, preferably by the endotherm knife or actual cautery. The tumor bed may then be exposed to a much higher tissue dose of radiation than would be possible if the same amount of radiation were filtered through one or several centimeters of overlying tumor tissue.

### DISCUSSION

From this account it may seem that surgery has been advocated as the treatment of choice for most skin cancers. Careful study, however, will show that these indications are not concerned with the great majority of skin cancers, but in reality affect a relatively minor group. Melanoma, fortunately, is not a common disease, nor is burn scar cancer or xeroderma pigmentosa, and most of the other lesions listed.

In such a discussion as this the contraindications to surgical treatment should be considered. Obviously, surgical measures can be made to cure any skin cancer that radiation can cure, and also some others that cannot be controlled by radiation. However, when radiation is used by an expert, it will produce a better cosmetic result and cure the lesion more simply than will surgery, with the exceptions as discussed in this communication. In this connection it should be stated that most authors believe that early carcinoma about the eyelids should be treated by radiation, cancer in this location being considered a contraindication to surgical treatment. Again it must be emphasized that irradiation by skilled therapists is referred to, and not the casual use of radium or x-ray by someone not thoroughly familiar with this field. Serious damage to the eye, particularly the lens, may result from injudicious irradiation of this area. When a cancer of the eyelid has invaded the

structures of the orbit, then the contraindication to surgery is reversed, and the orbit should be exenterated.

Each problem in skin cancer should be treated on its own merits, and requires individualization in judgment and technique. Only broad generalizations can be made about any form of treatment and the specific details of each case must be considered separately in outlining a treatment plan.

## SUMMARY

Both surgery and radiation have special advantages in the treatment of certain types of skin cancer. In this article the phases of malignant tumors of the skin which are best suited to surgical attack are discussed. They have been considered in the following order:

1. Prophylaxis: moles and postradiation keratosis.
2. Surgery in specific types of skin cancer: melanoma, residual or recurrent disease, radiation cancer, and burn scar cancer.
3. Considerations of anatomic location and extent: scalp, ears, midline lesions, cancer in skin adjacent to bone, perineum, and skin cancer invading bone or cartilage.
4. Skin cancer complicating specific skin diseases: xeroderma pigmentosa, acrodermatitis chronica atrophicans, and lupus vulgaris and lupus erythematosis.
5. Regional node metastases.
6. Surgery as an adjunct to radiation.

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# Recent Advances in Surgery

CONDUCTED BY ALFRED BLALOCK, M.D.

## RECENT ADVANCES IN THE TREATMENT OF PERIPHERAL ARTERIAL EMBOLISM

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THE treatment of arterial embolism is a subject of considerable practical importance. The condition is not rare and the results without therapy are poor indeed. Griffiths (1938) found that 87 per cent of the patients not operated upon were dead within a fortnight and all the remainder required major amputations. The treatment of this condition is not simple and if anything is to be accomplished at all it should be done promptly. In addition to several forms of therapy in use for some years, the recent introduction of several newer modes of attack upon this most serious of conditions furnished the opportunity of a reappraisal of the entire question. The following article attempts to correlate past experiences in the treatment of acute embolic arterial occlusions with the present status of the newer forms of therapy.

### HISTORICAL

Severeanu (1894), professor of surgery at the University of Bucharest, is the first who recorded attempts at embolectomy. This author was apparently fully acquainted with the predilection of localization of emboli at the bifurcation of vessels and with their essentially cardiac origin. He did not use his method, however, to make a complete cure, but to preserve the vitality of amputation stumps, essentially of the lower limbs. He would amputate close to the level of gangrene in embolic cases and then insert an oiled catheter up the proximal stump of the occluded artery. In many cases a clot would come away and not only would the reopened artery bleed, but "l'hémorrhagie capillaire est devenue plus abondante et les tissus prirent une couleur plus vive." Healing by primary intention usually occurred in these cases.

The first real attempt at removal of an embolus by arteriotomy was made by Ssabanejeff (1895). This author unsuccessfully tried to remove an embolus from the femoral artery in a case of embolic threatened gangrene of one leg in a 28-year-old woman with rheumatic fever

and ulcerative endocarditis. Key (1921) stated that Ssabanejeff did not find the embolus. The patient agreed to amputation and it was done lower down and the wound in the vessel was sutured. Death occurred nineteen days later and necropsy revealed that the vessel was patent at the point of suture.

Moynihan (1907), of Leeds, removed a popliteal embolus and the patient died four days later. Handley (1907) attempted an iliac embolectomy but could not remove the clot. Stewart (1907), of Philadelphia, did a femoral embolectomy which almost was successful. An embolus at the bifurcation of the common femoral artery was removed thirty-six hours after lodging in the presence of gangrene of the foot. Pulsations reappeared down to the knee and gangrene was limited to the calf and below. Amputation at the level of the tibial tubercle was performed on the forty-second day. Lilienthal (1907) suggested the use of end-to-end arteriovenous angiorrhaphy for peripheral arterial embolism, but naturally this operation was not widely adopted. John B. Murphy (1909) did a femoral embolectomy but had to amputate the leg. Lejars (1902) removed an arterial thrombus. Twelve embolectomies were done in all before Georges Labey did the first successful one in 1911.

The first successful embolectomy was performed by Georges Labey on Nov. 16, 1911 in the Hôpital Saint-Antoine, Paris, and reported by Mosny and Dumont at a meeting of the Academy of Medicine of Paris a month later. The patient, a man aged 38 years, with mitral stenosis, was operated upon by Labey under local anesthesia six hours after the lodging of a left femoral embolus. The clot was removed directly through an incision in the artery 1 cm. long and after suturing, the vessel circulation returned. The next day, thirty-six hours after the operation, pulsations were felt distinctly in the posterior tibial artery and at the time of reporting, thirty-three days after operation, the patient was improved and the left leg was entirely well. A year later, in 1912, Einar Key of Stockholm did the first of his series of seventeen embolectomies on fifteen patients reported in 1921 to 1922. Reviews of the literature are given by Key (1921-1922), quoting thirteen successes out of forty-five cases; Jefferson (1925) quoting twenty-eight successes out of seventy-three cases; Petitpierre (1928) quoting thirty-four successes out of 118 cases; and Key (1929) quoting approximately eighty-six successes out of 216 cases. Key's article in 1921-1922 is the classic in the field of embolectomy and so great has been his influence that of the 216 cases collected to the end of 1927, 145 were done in Sweden. American and English reviewers agree on the preponderance of Swedish cases and Pemberton (1928) stated that up to 1928 only twenty cases were reported in the United States and Canada. Recent reviews include those of Lahey (1926), Reid and Andrus (1927), Andrews and Harkins (1932), Pearse (1933), Danzis (1933), Linton

(1941), Pratt (1942), and Lesser (1943). The book of Haimovici (1937) on *Les embolies artérielles des membres* which is 336 pages long is the largest work extant exclusively devoted to this subject.

### DIAGNOSIS

The essential features in the diagnosis are the sudden onset of pain, usually in one of the lower extremities, with blanching, loss of sensation, and loss of local heat. Generally, except in aortic cases, the circulation to the opposite extremity is fairly competent. Bull (1921-1922) found 181 instances of parietal cardiac thrombi in a series of 6,140 necropsies, testifying to the frequency of this condition and the resultant dangers of embolism. Garvin (1941) also discussed the importance of the presence of mural thrombi in the left side of the heart in the causation of peripheral embolism. Danzis (1933) also pointed out that the origin of most of the emboli is from the heart and that the most common site for lodging is one of the femoral arteries. In Key's statistics (1921-1922), the left arm and left leg were involved more than the right. Forty-one of 46 cases of arterial embolism observed by McKechnie and Allen (1935) occurred in cases of heart disease. In the diagnosis of arterial embolism, Edwards (1941) outlined the differentiation from nonarterial disorders which simulate disease of the peripheral arteries. DeTakats (1936) pointed out that in some of his cases of peripheral arterial embolism pain was entirely absent. In the diagnosis, oscillometry and arteriography are useful in localization. Haimovici (1937) especially advised arteriography. Nordentoft pointed out that the downward thrust of the embolus itself may be confused with the arterial pulsation and that the embolus actually lies a little higher than the lowest palpable pulse. In speaking of the disappearance of the pulse (asphygmia) Haimovici (1937) stated: "l'absence du pouls, de règle dans les embolies artérielles, constitué un des meilleurs signes cliniques." This author also recognized the importance of Nordentoft's sign, pointing out that the pulse may be felt in some cases several centimeters distal to the obstruction due to a pulsation transmitted by the clot itself. Pulsation of the artery below the embolus has also been noted by Deitch (1936), Griffiths (1938), and by one of us (H. N. H.) in several personal cases. Deitch and Griffiths stated that such a pulsation preoperatively has no connection with prompt return of the distal pulse after surgery. Heanley (1939) also noted the thrusting type of impulse felt in an artery just below an embolic obstruction. In his two cases this occurred in the femoral region.

Haimovici (1937) pointed out that pain comes on as a veritable *coup de fouet*. Its sudden appearance and violent character constitute a major symptom of arterial embolism. It is probably due to reflex spasm rather than to direct irritation from the embolus.

Premonitory signs of embolism are vague and are probably due to breaking off of small embolic fragments before lodging of the main clot. Movement of the main clot from a straddle position to a more obstructive one may account for some of the symptoms noted. In most cases the reflexes are weakened or abolished and sense of position is absent. Haimovici (1937) quoted Gallavardin and Contamin, Achard, Leblanc and Rouillard, Sencert, Ravault, Langeron, and others as observing that the onset is not always rapid but may be slow and progressive.

*Oscillometry.*—This method has been used by Haimovici (1937) and others. It essentially is a more delicate method of noting where the arterial pulse becomes weaker or disappears. Haimovici points out that there are three zones: normal pulse, diminished pulse, and absent pulse. The obliteration is often at the proximal end of the middle zone.

Another useful test is the reactive hyperemia ring test of DiPalma, Muss, and Foster (1942) which may prove of value in the differential diagnosis of peripheral arterial embolism.

*Local Hypothermia.*—Haimovici (1937), as well as others, has pointed out the importance of decrease in local temperature after lodging of an embolus. This is not only objective, but subjective. In advanced cases one finds a typical *froid cadavérique.* Ipsen (1931) believes that a temperature difference of 1° C. between two extremities indicates a pathologic condition and the greater the difference, the more serious the ischemic condition. Antonioli stated that there is often a hyperthermic zone at the upper level of the ischemic region and that observation of this will indicate the level of gangrene.

*Nervous Changes.*—Aside from those listed above, Haimovici pointed out that there is often a loss of voluntary motion. Generally the loss of sensation does not extend as high as does the discoloration and coldness. Deep sensation is occasionally exaggerated, but in general decreases in proportion to the loss of superficial sensation.

*Differential Diagnosis.*—In this respect, several conditions which are not benefited by operation should be particularly considered. These include especially arteriosclerosis with arterial thrombosis, as well as arterial spasm, thrombophlebitis, and Buerger's disease. An example of such a faulty diagnosis is demonstrated by Case 1.

CASE 1.—H. Ba., a widow, aged 74 years, with a history of arteriosclerosis and hypertension of several years' duration was noted to have auricular fibrillation in January, 1941. She was admitted to the hospital for several days at this time. Eight days afterward, on Feb. 9, 1941, she had sudden pain in the left leg, of acute onset with numbness. She came to the hospital two days later at which time there was coldness and duskiness of the left foot. Immediately after admission she was seen and although thrombosis on an arteriosclerotic basis was considered most likely, embolism could not be ruled out.

Exploration of the left popliteal artery was performed under spinal anesthesia by one of us (H. N. H.) after left paravertebral novocain injection, and operation

was followed by continuous drip heparin administration. Some papaverine was given postoperatively, but no pavaex was used.

The paravertebral injections caused no improvement in the coldness of the foot or leg, so a femoral incision was made and the femoral artery explored with the finger down into Hunter's canal without opening the artery. A good pulsation could be felt, therefore this wound was quickly closed without drainage and the patient was turned on her face.

A popliteal vertical incision was made, coming down on the popliteal artery. We found that it was distended, hard, and nonpulsating. A longitudinal incision was made, 1 cm. long. This revealed a nonadherent clot. The clot extended upward three to four inches into Hunter's canal and after cleansing out the upper end, no definite embolus could be found, merely an extension of the clot, and a good pulsatile blood stream occurred. Milking the clot from below the site of incision in the artery, we found that all three branches of the popliteal artery were full of these clots. The anterior tibial artery was cleansed to where it perforated the intermuscular septum. The posterior tibial artery was found to be very hard with evidently a thick wall and incision ½ cm. long made in it, and a definite communication made between the two incisions. The peroneal artery seemed to be better in nature than the posterior tibial, but it could only be cleansed down several inches. Thus, the whole system seemed to be riddled with these clots, which all had the same appearance. The vessel walls were sclerotic and involved, and it was decided that this was a thrombotic process rather than an embolic one. The clots which were removed are shown in Fig. 1.

Fig. 1.—Popliteal thrombus of H. Ba., Case 1.

However, two inches below the branching of the peroneal artery, all three branches were cleansed and a pulsation of all three branches was obtained. The lower incision was sewed up with a single row of interrupted fine white silk and the upper incision was sewed with a double row of continuous fine white silk. Then, 4 c.c. of heparin were injected into the artery and definite pulsation continued. However, this did not extend down much beyond the level of the wound. The blood did not seem to be flowing through. The wound was closed without drainage. The appearance of the leg afterward was not much different than at the onset. Continuous heparin injection was advised and papaverine kept in reserve.

Anesthesia for the procedure consisted of spinocaine 1.75 c.c. expanded to 4.0 c.c. The spinal anesthetic was given shortly after the paravertebral injection. The patient left the operating room in fairly good condition. The leg did not improve in

appearance and the heparin was discontinued on the fourth postoperative day because of bleeding from the popliteal wound. The general condition failed and definite gangrene was evident in the left leg. Death occurred two weeks after operation.

This case demonstrates the futility of arterial thrombectomy in a patient of this age. The operation was done in the belief that an embolus might be present, but this hope was not realized.

## GENERAL CONSIDERATIONS

*Collateral Vessels.*—Collateral vessels have an especial importance in planning the operation of embolectomy. Finch (1934) reported a case in which he removed an embolus by the retrograde method with Key's probe. Immediately both ends of the vessel showed free bleeding, indicating opening of the collaterals. He tied the artery on both sides of the incision, and divided it, recovery ensuing. A colleague of his did the same, only in a case without bleeding from the distal end with disastrous results, indicating the importance of the collateral circulation. The procedure of trying to milk an embolus down without removing it has been suggested. Without knowledge of the collateral circulation, such a procedure is apt to be dangerous because even though the embolus moves from a critical position, there is no assurance that it will go to a safer one.

*Secondary Thrombosis.*—Extension of the original clot into side branches of the artery was discussed by Schmorell (1933), Girdlestone (1935), and Haimovici (1937).

True secondary thrombosis, however, denotes formation of a new clot, usually at the site of arteriotomy, and in the preheparin days was the chief hazard in embolectomies. Burnett (1939) reported a case of embolism of the brachial artery in which the artery was opened three times. Each time pulsations gradually ceased after about sixty seconds and on reopening, a new clot was found. Doberauer (1907) performed an axillary embolectomy fifty-two hours after the onset of the condition, extracting a clot 3 cm. long. Because of immediate rethrombosis he did an arteriovenous anastomosis with unstated results. Bérard (1909) did a temporarily successful embolectomy on the femoral artery, but secondary thrombosis occurred immediately, taking away from this author the honor of doing the first recorded successful case. Wreden (1913) removed an aortic embolus by retrograde sounding with a catheter but the next day recurrent thrombosis necessitated amputation. This whole subject is discussed by Nyström* (1936). In one of his cases, secondary thrombosis occurred twice, but with true patience, Nyström reopened the vessel twice, removing the clot, and the second time (third arteriotomy), he injected heparin with a perfect result.

*Page 25 of Reference 154.

The chief means of preventing secondary thrombosis are (1) choice of early cases with normal vessel walls, and (2) the use of heparin in the vessel after closure of the arteriotomy wound.

Not only are secondary thrombi apt to occur (Schein, 1935), but other emboli are frequent. In fact, a good share of temporarily successful embolectomy patients subsequently die from other emboli.

Some years ago the senior author (R. D. McC.) analyzed two groups of cases of embolism and thrombosis. One of these groups (177 cases) was seen at the Johns Hopkins Hospital before 1916, and the other (46 cases) was observed at the Henry Ford Hospital after 1916. Of the entire group of 223 cases, 163 patients died and 60 recovered. Most of the cases were medical in nature, but some (about one-third) were surgical. The most common type of embolism was pulmonary (82 cases in the Johns Hopkins series and 15 in the Ford Hospital series). In the entire group there were 41 instances of femoral thrombosis or embolism, only 3 being called embolism. It is interesting that of 12 cases of femoral thrombosis in the Ford Hospital series, all but 2 were on the left side. There were 3 cases of aortic thrombosis and 1 of aortic embolism. Three cases each of brachial embolism and subclavian thrombosis were noted, while iliac and pelvic thrombosis (probably includes some venous cases) were noted 21 times.

The complication of pulmonary embolism occurring during an embolectomy (that of the common iliac artery) as described by Crowe (1942) is unique. It is well known that many patients with peripheral embolus later die of pulmonary emboli. Therefore, this accident occurring during operation is not so surprising as it would seem at first glance.

*Concurrent Venous Thrombosis.*—Haimovici (1937) made an extensive analysis of this problem, as a concurrent venous thrombosis occasionally is noted associated with arterial embolism as in our Case 2. Haimovici concluded that extension of the thrombus intravascularly in continuity is not the chief item in these cases. The important factor is, he decided, a transverse propagation by contiguity. This accentuates once more the importance of the adventitia in these cases. It not only conditions the noxious vasomotor reflexes in these cases but also increases the hazard of associated venous lesions. Our Case 2 furnishes supportive evidence for this theory of Haimovici's, as there was so much periarteritis present that separation of the popliteal artery and vein were extremely difficult.

Case 2.—D. B., a married woman, aged 78 years, with arteriosclerotic heart disease, auricular fibrillation, and arterial hypertension was admitted with a history of sudden pain in the right foot beginning twenty-four hours before with rapidly developing signs of arterial obstruction. Despite the fact that arterial thrombosis seemed likely, the possibility of embolism caused a decision for operation to be made which was performed by one of us (H. N. H.).

*Operation.*—Examination of this patient revealed a sock-like discoloration of the foot extending up about five inches above the malleoli of the ankle. Just above the upper layer of this discoloration, there was an area of hyperesthesia and hyperalgia. The area of discoloration and sensory defect seemed to coincide. The patient could move her toes easily. Temperature curve was taken, a paravertebral injection was done on this right side, and 10 c.c. of 2 per cent novocain were injected into each of four needles placed two fingerbreadths lateral to the spine and two fingerbreadths deep to the transverse processes. A moderate temperature response occurred. The temperature of the right shin improved relatively 5° F., but the right large toe improved relatively only 2° F. The patient was then observed for about twenty minutes. In the absence of oscillometer, we took a blood pressure cuff and tested both legs. The fluctuation was rather marked in the left thigh and weakened in the right thigh. There was a moderate fluctuation at the left knee but none whatsoever at the right knee. To direct palpation the femoral pulses were both strong, whereas both popliteal pulses were not palpable. We decided to do a popliteal exploration.

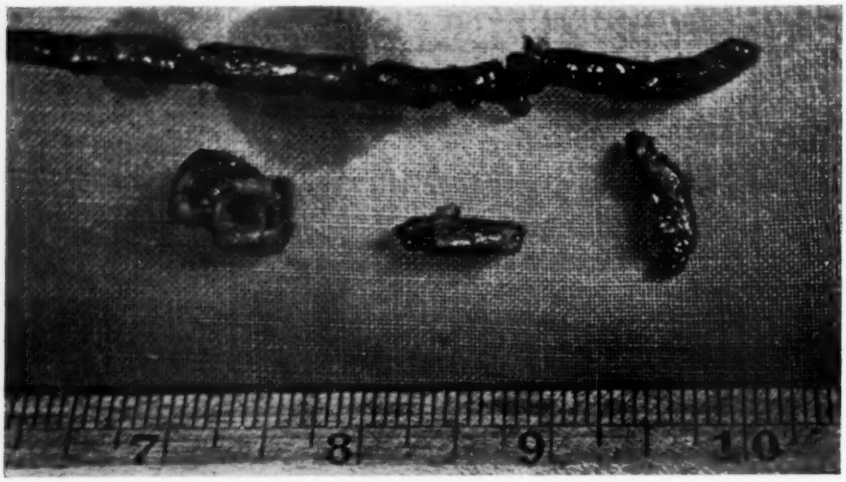


Fig. 2.—Popliteal thrombi of D. B., Case 2, above; with segments of artery removed by arteriectomy, below. (Scale in inches.)

It is to be noted that, if we had followed the result of the oscillometer reading, we would have done a femoral exploration, which would have been better. The patient was explored in the popliteal region, using novocain anesthesia, through a vertical incision five inches long. Great difficulty was found in separating the popliteal artery and vein because of dense inflammation of the adventitia of the arteries and to some extent of the vein. The three branches of the artery were identified and just above them, the popliteal artery was opened by means of a vertical incision 1 cm. long. A clot was present. Palpating and milking the three branches caused some clots to pass and milking way up above in Hunter's canal by placing the finger up there caused a large amount of clot to come down followed by some blood. Exploration with the uterine probe and catheter also removed some clots, the upper portion of which was whitish and appeared somewhat like an embolus. However, we were not able to free the vessel completely and observation of the three branches indicated that there was a nest of clots in all of them. No blood came out from the peripheral end of the popliteal artery at any time. At the end of this exploration, the flow of blood from the popliteal artery was not noticeable at all. In other

words, it was definitely poorer than earlier in the procedure. Because of the patient's condition, we did not feel it advisable to explore the femoral artery. It was felt that the embolus itself was palpated in the bifurcation of the femoral artery (see Fig. 2).

Because of the patient's condition and age, we decided to do an arteriectomy, which was performed 1 cm. above the incision in the artery, downward, including the two uppermost branches of the popliteal artery. We also noted at this time that there were definite clots in the popliteal vein and we decided to ligate this vein. This was done and the wound was then closed with interrupted silk for the fascia and interrupted skin silk without drainage. No local heparin was injected but the patient was to be started on continuous intravenous heparin.

At the close of the procedure, there was very little change in temperature of the leg as compared before operation, but it seemed to be definitely better than before the paravertebral sympathetic injection was done.

Despite the administration of heparin postoperatively, gangrene developed and the patient died on the eighth postoperative day. During the last few days of life, marked gangrene of the left (unoperated) leg was also present.

This case demonstrates again the futility of operation in a case of arterial thrombosis. An addition to the history, obtained from a relative after operation, showed that this patient had suffered from severe pain with icicle coldness in the right foot for eight weeks before operation.

*Paradoxical Embolism.*—Paradoxical embolism, through a patent foramen ovale into the heart, was discussed by Koritschoner (1936). Carling (1934) and Haimovici (1937) discussed peripheral emboli of such origin.

*Multiple Emboli.*—Multiple emboli have been reported by several authors, including Harkins (1934) and MacFarlane (1940).

### SPECIAL EMBOLI

Emboli in certain locations require special treatment. Such individualization applies especially to the arm and to the aorta, as will be discussed. While the most common site of lodging of the embolus is the origin of the left femoral artery, other sites each have a special significance. Embolectomy of the popliteal artery apparently should be a simple procedure, but because of danger to the collateral blood supply about the knee, in actuality the procedure is fraught with more than ordinary risk to the extremity.

*Arm.*—The arm is one region where special indications for embolectomy exist. Lund (1937) showed that the local results following embolectomy in the arm are almost twice as likely to be successful as in the leg (86 per cent as opposed to 48 per cent respectively). The percentage of success as far as life is concerned, however, was little better in the case of the arm (43 per cent as opposed to 35 per cent). These figures are of necessity lower than the local results given above as they include the deaths as well. While patients with embolectomy in the arm were just as likely to die as those with it in the leg if not operated upon, in no case did gangrene result. Lund concluded, there-

fore, that "no benefit is gained by such operations on the upper extremity." It is of interest that in Lund's entire series, of the 27 patients submitted to operation, 37 per cent were successful, while of 29 patients not submitted to operation, only 8 per cent were successful. Patients who did not have embolectomy nearly all died whether or not there was gangrene or amputation.

Graham (1937) reported 10 embolectomies performed at the Toronto General Hospital. Three operations done on the upper extremities were successful, but only 2 of 7 done on the legs led to improvement. Pearse (1933) also noted the much more favorable results in upper extremity cases. DeTakats (1936) agreed with Lund (1937) that embolectomy is seldom indicated in the upper extremity.

An illustrative case of upper extremity embolism is as follows.

CASE 3.—P. H., a man, aged 53 years, with known arteriosclerosis and arterial hypertension for at least two years, developed a coronary attack with auricular fibrillation. On March 7, 1943, he had a sudden pain with numbness in the left hand and arm. He was admitted to the hospital three hours later at which time pulsations could be felt in the upper but not in the lower portion of the brachial artery. The hand and forearm were markedly discolored, cold, and anesthetic. Because of the fact that the involvement was in the arm and because of the patient's desperate condition (Cheyne-Stokes respiration, râles at both lung bases, disorientation), embolectomy was decided against. Treatment included papaverine intravenously and stellate ganglion novocain block. The success of the block was attested by the development of an immediate Horner's syndrome. The gangrenous process remained constant and the patient died the next day, twenty-four hours after lodging of the embolus. At necropsy the left subclavian and brachial arteries were opened, revealing a recent embolus which extended from a point 2.5 cm. superior to the origin of the profunda brachialis downward for a distance of 11.5 cm. The embolus was essentially homogeneous throughout, there being no evidence of secondary thrombus formation. It was not adherent to the intima.

It was decided that the length of this embolus (11.5 cm.) blocked off the collateral vessels as well as the lumen of the brachial artery itself. This fact, plus the general extreme condition of the patient, contributed to the lack of improvement following conservative therapy.

*Aorta.*—Embolism of the aorta is one of the most serious of all types of peripheral arterial embolism. The bifurcation is involved in most instances. In Hesse's series (1921) of 42 aortic emboli in which the site was known, 25 were at the aortic bifurcation, 2 in the thoracic aorta and 12 in the abdominal aorta above the bifurcation. Of 49 unoperated cases of aortic embolism reported by Hesse (1921), 1 or possibly 2 recovered spontaneously. Hesse (1921) reported a case of aortic embolism and another of aortic thrombosis and collected 71 other such cases from the literature. Fifty-three of these cases were embolic in nature and of these, 36 were definitely of cardiac origin. A sudden onset was observed in 97.5 per cent of the embolic cases and in only 28.5 per cent of the thrombotic cases. Hesse also collected 14 cases of ligature of the aorta with 14 deaths (see Table I). Experience

with his entire series of 73 cases led Hesse to conclude that aortic emboli are commoner in men, aortic thrombi commoner in women. He favored an aortic approach for embolectomy and opposed retrograde probing. In the entire series, the mortality of the untreated cases was 92 per cent. In 52.2 per cent (also includes the thrombi cases) the patients lived a week at least, so that sudden death was rare. The aortic bifurcation was the site of the obstruction in 52.5 per cent of the cases. Hesse opposed simultaneous vena cava ligation.

TABLE I

INCIDENCE OF GANGRENE AFTER ARTERIAL LIGATURE

| SITE OF LIGATURE | PERCENTAGE OF GANGRENE | | |
|---|---|---|---|
| | WOLFF | HEIDRICH | MAKINS |
| Axillary | 15.0 | 9.8 | --- |
| Brachial | 4.0 | 3.1 | --- |
| Aortic | --- | 100.0 | --- |
| Common iliac | 50.0 | 100.0 | 40.0 |
| External iliac | 11.2 | 13.4 | 16.6 |
| Common femoral | 25.0 | 21.8 | 25.9 |
| Superficial femoral | 12.7 | 10.4 | 14.1 |
| Popliteal | 14.9 | 37.2 | 32.5 |

Siegel and Garvin (1941) reported an unoperated case of thrombosis and embolism of the abdominal aorta with concomitant obstruction of the renal arteries and fatal issue. At the Cleveland City Hospital from 1930 to 1939, inclusive, they saw 9 such autopsied cases, in only 2 of which, however, was there renal obstruction. O'Shaughnessy (1934) also reported a case of aortic embolism, not operated upon, in which there was suppression of the urine in addition to the usual signs. Necropsy revealed the infarction had taken place at the level of the renal arteries. In Hesse's series (1921), 23.3 per cent of the patients had renal infarction.

The prognosis without operation is thus almost hopeless. Welch and Rolleston (1909) stated that three patients (reported by Gull, Chvostek, and Nunez) had survived without operation. Neuhof (1932) claimed to have seen a spontaneous cure. In all the remaining reported cases the patients have died, save two reported by Hesse (1921), who survived double amputations. In an extensive review, Hesse studied reports of 53 patients with aortic emboli, of which all but 4 died (96 per cent mortality). Mason and Warren (1931) collected 116 cases of aortic embolism, including one operative case of their own in which recovery did not take place. Griffiths (1938) collected 5 more cases from the literature and added 3 of his own, making a total of 124 cases. Of these, 28 patients were operated upon, 1 twice, with 9 successes in 28 operations. Of the 9 reported successes, 7 were operated upon during the first six hours. Patients with ligation of the abdominal aorta have lived one year (Matas, 1925) and three months (Brooks,

1926). Experimental studies in ligation of the aorta by Brooks (1926) and by Brooks, Blalock, and Johnson (1928) revealed little, if any, change in the blood pressure in the artery proximal to the occlusion.

Griffiths (1938) collected 9 successful cases of aortic embolectomy. Haimovici (1937) found 9 such cases, including that of Gohrbandt which was not in Griffith's series. Griffith's case was included in a report of 8 cases of arterial embolism seen at the Manchester Royal Infirmary. In this article, Griffiths (1938) described the first successful British aortic embolectomy and also reported the first diagnosed case of carotid embolism. In his series of 8 cases he did 3 embolectomies with success. His single successful aortic case was, according to him, the ninth successful one on record.

Gohrbandt (1933) reported an additional successful case, as did Culmone (1938). Gohrbandt operated first on the left femoral artery, then opened the aorta. Lindgren's patient (1939) received heparin for nine days postoperatively. Murray (1941) reported two successful aortic embolectomies, heparin being used in conjunction with operation. Pratt (1942) reported an additional case of aortic embolectomy which was successful except that one leg had to be amputated at the knee. McMaster's (1939) two months' cure of aortic embolism following iliac embolectomy is too atypical to include in this series. This author reported that spinal anesthesia caused an immediate improvement in his patient. Walzel's case (reported by Kaps and Walzel, 1930-1931), was fortunate in that operation was done 40 minutes after onset. The patient was a man, aged 38 years, with endocarditis lenta. An abdominal approach was used and there was a good result with restoration of the dorsalis pedis pulse on both sides, but death occurred from the cardiac condition twenty-five days later. Necropsy revealed no local recurrence. Wikle and Cabot (1943) reported an aortic embolectomy performed four hours after the lodging of the embolus. The left leg was saved, but amputation of the right had to be performed two weeks after the original operation. Two weeks after this the patient died.

Groth (1939) concluded from a study of 46 embolectomies done at the Surgical Clinic, Uppsala, that in cases of embolism at relatively inaccessible sites (e.g., aorta, common, and external iliacs) the following rule should be adopted:

"Bei Operation von peripherer Embolie mit schwer zugänglicher Lokalisation soll in erster Linie retroperitoneale Hinuntermelkung des Embolus und Arteriotomie an leicht zugänglicher Stelle versucht werden, und erst wenn dies nicht zum Resultat führt, soll man zu versuchen mit retrograder Sondierung übergehen, evtl. danach zu direkter Embolektomie."

In the Uppsala series of 46 embolectomies, there were 5 aortic cases, 4 treated by milking and 1 by retrograde sounding without removal of the embolus. Milking was used in this series 13 times as compared to 9 times for retrograde sounding in 22 cases (5 aortic bifurcation,

11 common iliac, 6 external iliac). The cases treated by the milking method were more successful than those treated by retrograde sounding. This applied to the number of these difficult cases in which the embolus could be removed at the first attempt (10 of 13 in the milking cases, 3 of 9 in the sounding cases) and also to the frequency of secondary thrombosis (0 of 4 in the milking cases and 4 of 5 in the sounding cases). Finally, the long-term recoveries were much more frequent in the series treated by milking. It should be stated, however, that on further analysis of the series of cases, it is seen that the best results were obtained in those patients treated by milking after unsuccessful retrograde sounding.

The method of Nyström, "retroperitoneale Hinuntermelkung" or retroperitoneal milking down of the embolus, was first used by him in his clinic in Uppsala in 1923. By either cutting or freeing Poupart's ligament, the hand is introduced retroperitoneally until the embolus is felt and milked down to the femoral arteriotomy where it is removed. To prevent fragments coming down the opposite femoral vessel, it too should be opened and temporarily clamped off with a soft rubber tube. The embolus may be first crushed against the promontory of the sacrum. If embolic fragments escape into the hypogastric vessels, no harm is done. The femoral vessels, however, should be kept closed by rubber tube traction to prevent escape of embolic fragments into them. Nyström believes that retrograde probing should be used only in cases with undiseased arteries.

Nyström performed a successful embolectomy on the aortic bifurcation and nine months later, Westerborn did another embolectomy at the same site following which the patient lived five years, death resulting from uremia. Key (1936), Schmorell (1933), and Jefferson (cited by Griffiths, 1938) used the retrograde milking method of Nyström.

A collection of 19 cases of successful aortic embolectomy is shown in Table II. This table is based partly on Griffiths' (1938) collection of 9 cases, but as the case he lists by Hindmarsh and Sandberg (1936) is the same as his second case by Key (1922), his table should only include 8 cases. Nyström (1936) states that Crafoord (1933) did a successful aortic embolectomy, but we could find no other record of this case. Schmorell's patient, a 66-year-old man with a straddle embolus of the aorta following appendicitis, was cured for at least five weeks by embolectomy by Nyström's extraperitoneal milking from below. In this case the advantages of the extraperitoneal approach in the presence of peritonitis were manifest. Usadel (1932) used a long lumbaringuinal incision with a retroperitoneal approach. The similarity in shape of Bauer's (1913) and Drevermann's (1931) aortic emboli is noteworthy. Both were about 3 cm. long and consisted of a large crown or body with two roots, the crown lying in the aorta and the stubby roots in the two common iliacs. Key (1922) removed his embolus in five pieces.

TABLE II
SUCCESSFUL AORTIC EMBOLECTOMIES

| NO. | AUTHOR | DURATION IN HR. | SEX | AGE | SOURCE OF EMBOLUS | OPERATIVE APPROACH | SUBSEQUENT HISTORY |
|---|---|---|---|---|---|---|---|
| 1 | Bauer (1913) | 3 | M | 39 | Cardiac | Transperitoneal | Death in 2½ yr. |
| 2 | Key (1922) | 23 | M | 44 | Cardiac | Retrograde | Death in 10½ yr., from heart disease |
| 3 | Usadel (1931) | ½ | F | 44 | Cardiac | Retroperitoneal | Alive at 9 mo. |
| 4 | Drevermann (1931) | 6 | M | 41 | Cardiac | Transperitoneal | Alive at 12 mo. |
| 5 | Walzel (1930-1931) | 1 | M | 38 | Cardiac | Transperitoneal | Death in 25 days from heart disease |
| 6 | Nyström (1932) | ½ | M | 56 | Cardiac | Retrograde, milking | Recurrence in 9 mo. (see No. 7) |
| 7 | Westerborn (1932) | 6 | M | 56 | Cardiac | Retrograde, milking | Death in 5 yr. from uremia, same patient as No. 6 |
| 8 | Commando* (1933) | 2 | M | 68 | (Postop.) | Retrograde | Death in 3 wk. |
| 9 | Gohrbandt (1933) | 5 | F | 39 | Cardiac | Transperitoneal | Unknown |
| 10 | Schmorell (1933) | — | M | 66 | Appendicitis | Retrograde, milking | Alive at 5 wk. |
| 11 | Stegemann (1933) | 4 | M | 55 | ? | ? | Died after several mo. |
| 12 | Culmone (1938) | — | — | — | — | — | — |
| 13 | Jefferson† (1938) | 6 | M | 25 | Cardiac | Retrograde, milking | Death in 3 mo. |
| 14 | Lindgren (1939) | 10 (38‡) | F | 41 | Cardiac | Transperitoneal | Unknown (alive at 9 days) |
| 15 | Ravdin (1941) | 3 | M | 32 | Cardiac | Retrograde | Alive at 3 yr. |
| 16 | Murray (1943) | — | — | 19 | Cardiac | Right paramedian extraperitoneal | Death in 2¼ yr. from pulmonary embolus |
| 17 | Murray (1943) | 21 | F | 38 | Cardiac | Right paramedian extraperitoneal | Death in 4 mo. from cerebral embolus |
| 18 | Murray (1943) | — | F | 48 | Cardiac | Right paramedian extraperitoneal | Death in 2 yr. from cerebral embolus |
| 19 | Murray (1943) | — | F | 27 | Cardiac | Right paramedian extraperitoneal | Alive after 3½ yr. |

*Cited by Danzis (1933).
†Reported by Griffiths (1938).
‡Warning signs of pain in left foot (preliminary embolus ?).

Our only case of aortic embolectomy was unsuccessful mainly because of the long duration. It is noted in Table II that in 14 cases with the duration in hours recorded, all but 3 were six hours or less. There were 10 men and 6 women, and 11 of 15 were between 38 and 56 years of age. In all but two stated cases the origin of the embolus was in the heart. The transperitoneal approach was used five times, the retrograde milking method (Nyström) four times, the retrograde probing method three times, and the lumbar or abdominal retroperitoneal approach (Usadel or Murray) five times. All the patients recovered without amputation, but only 7 are known to have lived for more than one year after operation.

The best group of cases of aortic embolectomy is that of Murray (1943), who reported five successes. The circulation was restored in all five cases and the impending gangrene of both legs in each instance was immediately replaced by extremities with normal circulation and function, thus transforming the picture to that of the original healthy state. An extraperitoneal abdominal approach was used in all cases, extending from two inches above the umbilicus to the pubis as a right paramedian incision. Heparin was used at the time of operation in all instances. As it is assumed that these five cases include and are duplications of those briefly mentioned by Murray in 1941, these earlier cases are not included in Table II. It also is to be noted that Murray speaks in his 1943 article of five successes, but gives six case reports, two of the patients dying of other causes on the second day. Therefore, if these are excluded there were four successes, if not, six. It is not apparent how Murray considers he had five successes; only four are included in Table II.

The report of our case is as follows.

CASE 4.—J. L., a man aged 53 years, had diarrhea with black stools two years before the illness for which he was admitted to the hospital. For six months he had suffered from heart trouble and had lost ninety pounds in weight during this period. On Christmas day, 1940, he had diarrhea and was admitted to the hospital the next day. The first night he was in the hospital he had seven stools. At 7:30 A.M. on Dec. 29, 1940, he had a sudden onset of pain in both legs with loss of sensation, motive power, and normal warmth. At first a diagnosis of a neurologic condition was made by the resident staff, but the next day the patient was seen for the first time by Dr. Grain who immediately made a diagnosis of occlusion at the bifurcation of the aorta. At this time no pulsation was felt below the epigastrium and there was marked coldness and beginning color changes in both legs.

One of us (H. N. H.) was immediately called in consultation. The patient's condition without operation seemed hopeless, but with operation appeared to be almost equally as bad because of the length of time since the lodging of the embolus (twenty-nine hours). Operation was decided upon as offering the only hope for the patient's life. A preoperative diagnosis of straddle embolus of the aortic bifurcation was made. A preliminary bilateral paravertebral lumbar block of novocain was done without any demonstrable effect on the temperature of the legs. Operation was done at 1:30 P.M. on December 30, thirty hours after the probable lodging of the embolus.

*Operation* (H. N. H.).—Through a left herniotomy incision, going through all layers, the left iliac artery was exposed above Poupart's ligament. The inferior epigastric vessels which might have been a source of collateral supply to the leg, were sacrificed with this fact fully in mind to enhance the exposure in this markedly obese patient. The cord and associated structures were pulled downward. The artery had no pulsation. It was opened. The wall was sclerotic and fragmented. There was no definite clot present and no free blood. A No. 16 catheter could not be introduced more than one and one-half inch upward, whereas a No. 12 catheter could only be introduced about four inches. Flushing out with saline solution and rapid withdrawal of the catheter produced no result. It is of interest that autopsy later revealed that the difficulty in putting the catheter upward was due to narrowing of the lumen rather than to thrombosis or embolism.

Following this, the abdomen was opened through a hypogastric incision, extending from a little to the left of the umbilicus to near the pubis, cutting through the edge of the rectus sheath on the left side. No free fluid was present. The intestines were slightly darkened in their contents but the walls were quite viable. A diagnosis of some free blood in the lumen of the intestine was made but this proved at autopsy to be erroneous. Through very dense fat and markedly adherent tissue, which was later shown at autopsy, probably to be secondary to ulcerations of the aorta, this vessel was exposed near the fourth lumbar vertebral body and an incision was made one-half inch away from the aorta on the common iliac artery. This artery was also markedly sclerotic. A catheter could not be inserted downward, in spite of the fact that no thrombus was present at the site of opening and autopsy later disclosed this to be due to marked decrease in size of the lumen due to thickening.

The catheter was placed upward and flushed with very little result, but later, a No. 16 catheter was pushed upward about eight inches and definite blood obtained. Finally, using the finger to massage the lower end of the aorta, several fragments of clot were obtained, with relatively free pulsatile bleeding. Following this, in order to be sure that the right iliac artery was open, a vertical incision over the femoral artery on the right side was made below Poupart's ligament, and the artery exposed. It, too, had no pulsation. It was opened. A catheter could be placed up about six inches with no free blood obtained. There was still no pulsation in the aorta except one inch above the bifurcation but finally with massaging, another large segment of clot came out from the bifurcation and a very steady pulsatile flow of blood came out through the hole in the left common iliac. A definite clot was felt in the right common iliac, but despite considerable effort, we could not displace this.

The patient's condition was becoming poor. Try as hard as we could, we could not remove this clot on the right, and because of the poorness of the patient's condition, it was decided to sew the openings in the vessels. First that in the left common iliac was sewed, then that in the left external iliac, and then it was found that there was no pulsation any more in the lower aorta or left common iliac, so that the left common iliac had to be reopened and another large clot removed, this time followed by even better bleeding from the hole in the left common iliac. This was then closed but at that time only a slight flow of bright red blood, with practically no pulsation, came out of the hole in the right femoral artery, whereas from the left external iliac, no blood flow at all occurred, in spite of every effort. All the wounds were then closed, using interrupted skin silk for the incision over the right femoral artery, continuous heavy silk for the peritoneum, interrupted silver wire for the anterior sheath of the rectus of the abdominal incision, and through-and-through heavy wire through all layers of the incision over the left external iliac artery, which was entirely extraperitoneal.

The patient left the operating room quite conscious but still irrational, with a moderately good blood pressure, but we held forth no hope of eventual recovery because of the serious condition of the vessels.

After operating the patient's condition grew worse, there was no recovery of the circulation in the legs, and repeated temperature studies showed no improvement. He died at 1:20 A.M. on Dec. 31, 1940, twelve hours after operation. Necropsy revealed almost complete intimal occlusion of the left iliac artery, ulceration of the abdominal aorta with periarterial inflammation and intraarterial organized thrombosis. There were also organized thrombi in the right iliac artery. While this case may have had an embolus of the abdominal aorta grafted upon the older thrombotic and ulcerative process, this latter was probably the more important condition of the two. It is practically certain that without operation the patient would have died.

*Choice of Treatment and Decision as to Operability.*—Because of the urgency of the situation, early diagnosis and prompt decision are essential. As in perforated peptic ulcer and many other surgical conditions, the number of hours after onset is one of the chief factors affecting the prognosis. Thus, Funck-Brentano (1938) advised the following treatment of a peripheral arterial embolus depending on how long after the onset the patient is first seen.

1. Before ten hours: embolectomy plus vasodilatory and spasmolytic treatment (paravertebral, sympathetic injection, papaverine, and acetylcholine).

2. After ten hours: arteriectomy plus vasodilatory and spasmolytic treatment.

3. Late cases: arteriectomy.

In Key's (1936) series, 34 operations were performed within ten hours of the onset of symptoms, and of these patients, 19 (55.8 per cent) regained normal circulation. The results in the later cases were not so good. Schein (1935) also pointed out the value of early operation. Linton's results with various treatments are shown in Table III. In discussing the need for early operation, DeTakats (1936) stated, concerning his series of 15 arterial embolism cases, that in only 5 could exploration be done and only two were seen in the first 10 hours. Haimovici (1937) had the following system:

A. Under 12 hours

1. Medical treatment should be tentative and should not delay further indicated therapy more than 30 to 60 minutes. Medical treatment includes:

(a) Lumbar block of novocain

(b) Papaverine

TABLE III

COMPARISON OF DIFFERENT METHODS OF TREATMENT OF ACUTE ARTERIAL OCCLUSION IN LINTON'S SERIES (1937)

| METHOD OF TREATMENT | TOTAL NUMBER OF EXTREMITIES | EXTREMITIES SAVED | | EXTREMITIES LOST | | DIED TOO SOON | |
|---|---|---|---|---|---|---|---|
| | | NO. | % | NO. | % | NO. | % |
| Conservative | 17 | 5 | 29 | 7 | 41 | 5 | 30 |
| Embolectomy | 12 | 4 | 33 | 7 | 58 | 1 | 8 |
| Pavaex | 15 | 4 | 60 | 7 | 20 | 3 | 20 |

Medical treatment, if successful, continues two to three days. If it fails, use one of following:

2. Embolectomy

3. Arteriectomy (if wall is damaged, if poor condition of patient demands extreme haste, or if secondary thrombosis occurs)

4. Lumbar sympathectomy, especially as adjuvant to iliac or aortic embolectomies when done by the abdominal route

B. Over 12 hours

Again medical treatment should be tentative

1. Embolectomy rarely, but more often in aortic bifurcation cases. In such instances this should always be accompanied by a lumbar sympathectomy

2. Arteriectomy, in most cases

Haimovici concluded in this regard: "Quelle que soit la methode chirurgicale appliqué, les infiltrations [of the sympathetics] ou les injections d'eupavérine doivent toujours etre associées." He also pointed out that after unsuccessful embolectomy, about 45 per cent of the cases survive after amputation. Griffiths (1938) stated: "It is never the operation which kills these patients, but the disease which makes the operation necessary." In deciding whether or not to operate it should be borne in mind that the danger of gangrene after embolism is greater than after ligature, probably because of secondary thrombosis as well as the underlying cardiac condition. Nyström (1936) pointed out that the operation is less apt to be successful in old people or in those with diseased vessels. As to the general operability, Lund (1937) stated that he operated upon 27 out of 55 patients (25 embolectomies, 2 explorations of artery).

The indications for embolectomy have been broadened somewhat since the time of the first successful peripheral embolectomy in 1911. At that time, Mosny and Dumont set down the following rules:

"Les embolies vasculaires entrent donc maintenant dans le cadre des affections médico-chirurgicales, mais a condition qu'elles soient aseptiques, qu'elles soient opérées rapidement, que le sujet soit jeune, que ses artères soient saines, que l'embolie soit facilement abordable."

Pemberton (1928) states: "There is no established operative procedure of equal simplicity, fraught with so little risk and with such dramatic potentialities, that has been so woefully neglected as embolectomy for circulatory disturbances of the extremities."

General treatment includes conservative management with massage, heat, elevation, etc. The general care of acute arterial obstruction in the extremities was outlined by Scupham (1935). DeTakats (1936) and others have pointed out that a leg with embolic obstruction should not be elevated, but instead should be in a dependent position, some-

where between 10 and 15 degrees below the horizontal position. The use of heat is also less popular than formerly.

The chief modes of treatment, to be discussed in detail, include:

1. Sympathetic block (and lumbar sympathectomy)
2. Periarterial sympathectomy
3. Arteriectomy
4. Heparin
5. Papaverine and related drugs
6. Alternating positive and negative pressure
7. Amputation
8. Embolectomy itself

1. *Sympathetic Block and Lumbar Sympathectomy.*—The importance of sympathetic block in cases of arterial embolism should be borne in mind. Since the use of sympathetic block is based on relief of *arterial spasm*, a discussion of this condition which is a usual concomitant of embolism will now be given. Nyström (1936) pointed out that arterial spasm is the cause of the slow pulse return noted after embolectomy. The spasm caused by the internal irritation of an embolus is much like that caused by external irritation of an artery, producing "traumatic segmental arterial spasm" as reviewed by Montgomery and Ireland (1935) as well as in an editorial in the Lancet (1941), and of which several cases were reported as having been seen by Gage and Ochsner (1940). Åkesson (1937) and Duncan (1938) also believed that there was a spastic element in cases with arterial emboli. The case of Pridie's patient (1943) with gangrene of the leg following arterial contusion also demonstrated a vascular spasm. Despite the relief of the local spasm by exploratory operation, gangrene resulted.

DeBakey, Burch, and Ochsner (1939) approached this problem experimentally, stating: "It is evident that a chemical irritant placed either in the lumen of the main vein of the extremity or in the perivascular tissues of this vein produces a marked diminution of this volume (51.6 per cent) of peripheral pulsations. However, interruption of nerve pathways by local infiltration with procaine hydrochloride at the site of the chemical irritation or by resection of the lumbar sympathetic ganglia and chain abolished this effect."

In most cases sympathetic block (lumbar in the case of the lower limb; stellate ganglion in the case of the upper limb) is advised. Such injections of novocain were especially recommended by Leriche, Froment, and Vachon (1934), DeTakats (1936), Funck-Brentano (1938), Ravdin and Wood (1941), and DeTakats (1942). Gage and Ochsner (1940) reported on the use of sympathetic block in four cases of embolus of the femoral artery. In one case the embolus was removed after sympathetic block, but in all four cases the results were good. Roome (1941) was also one of the early advisers of sympathetic blockade in the management of arterial embolism and thrombosis. In both

his cases the relief of pain was quite marked following this procedure while previous large doses of morphine were relatively ineffective. In both cases, however, amputation had to be done.

Meyer (1940) had a 46-year-old male patient with evident embolism of the left iliac artery. Paravertebral novocain injection was done in the left lumbar region and exploration was then made of the femoral, popliteal, and tibial arteries. In each instance no visible pulse was present, but palpation did reveal pulsations. An incision in the tibial artery revealed a good flow of blood. It seemed evident, therefore, that the collateral vessels were opened by the paravertebral injection as evidenced by improvement in the temperature of the foot. The patient recovered except for a slight necrosis of the skin of the foot in several places.

Alcohol injections are less popular, but have been used occasionally. Thus, DeTakats (1937) used a paravertebral alcohol injection in the treatment of one case of postembolic occlusion.

Actual sympathectomy, chiefly lumbar, has been utilized. Thus, Bedrna (1936) of Königgratz, Czechoslovakia, reported two cases of embolism of the femoral artery treated by lumbar sympathectomy with healing. The first patient, a man aged 64 years, was treated for two days with novocain infiltration of the lumbar sympathetics on the affected side with only temporary relief after each injection. At the level of the second lumbar ganglion, 20 c.c. of 0.5 per cent novocain were injected at six and fourteen hours after onset. On the third day the third and fourth lumbar ganglia on the affected side were excised with healing four months later despite a pulseless femoral artery. Bedrna's second case, a woman, aged 66 years, with cardiac decompensation, also had an embolism of the left femoral artery. Twelve hours after onset, without previous novocainization, excision of the third and fourth lumbar ganglia was done with prompt relief of pain, improvement in appearance in nine hours, and recovery of the patient and of the limb despite an absent dorsalis pedis and popliteal pulsation. It is of interest that the cardiac edema disappeared much more rapidly on the side operated upon than on the other side (e.g., twelve weeks after operation, left leg edema-free; circumference of right thigh, 44 cm.; of left thigh, 40.5 cm.; of right knee, 27.5 cm.; of left knee 26 cm.). It is of interest that Bedrna reported paresthesias in one of his patients treated by lumbar sympathectomy. Besides the two cases of lumbar sympathectomy reported by Bedrna (1936), Häimovici (1937) lists two others with beneficial results.

The vascular spasm on the basis of sympathetic dysfunction in these cases seems, therefore, to rest on a firm foundation. Funck-Brentano (1938), in summarizing French views on embolism, lays most emphasis on sympathetic reflex disturbances caused by the local obstruction,

rather than on the obstruction itself. Schein (1935) also recognized the importance of the vasospastic element. Referring to obstructed arteries, Leriche (1927) stated: "The thrombosed arterial segment is no longer an artery, inasmuch as all arterial function has disappeared, but constitutes a sympathetic nerve in abnormal condition."

Haimovici (1937) did much experimental work on the problem of arterial occlusion. From this work he concluded that one of the chief elements in the pathologic physiology of peripheral arterial embolism is a vasoconstrictor reflex. This reflex originates from stimuli in the adventitia of the involved vessel at the point of blockage. One of the chief aims of therapy should be to suppress the vasoconstrictor reflex arc, either by acting directly on the reflexogenic zone (embolic segment) or indirectly by attacking the reflex arc at the origin of the vasoconstrictor nerves.

Other work indirectly applicable to this subject is that of Mulvihill and Harvey (1931) who found that simultaneous removal of the lumbar sympathetic ganglia would prevent the lowering of temperature (10 to 30° F.) of the affected limb which normally accompanies the ligation of the external iliac artery. Harvey and Halpert (1931) showed that the temperature-sustaining action of the sympathectomy occurs even when spinal cord section or posterior root section has been done. Furthermore, the two latter procedures have no effect in preventing limb temperature decrease after external iliac artery ligation.

All of this work also supports the rationale of the second and third forms of treatment discussed below.

2. *Periarterial Sympathectomy.*—In most cases of embolectomy, more or less of a periarterial sympathectomy is done in freeing the artery. Special emphasis has been placed on this stage of the procedure by Haimovici (1937), who pointed out that periarterial sympathectomy serves a double purpose. It removes the damaged adventitia and it prevents conduction of the spastic sympathetic reflexes. Schein (1935) and others have pointed out that the periarterial sympathectomy incidental to the exposure and stripping of the vessel serves as a temporary aid to collateral blood flow and to the removal of the embolus and adjacent thrombi. Periarterial sympathectomy has been used by Leriche for many years for a variety of arterial lesions. It relieves vasospasm, but not as completely as a cervical or lumbar sympathectomy. The latter operation is too severe, however, for use in these gravely ill patients, so the use of arteriectomy has been substituted.

3. *Arteriectomy.*—The first arteriectomy for peripheral arterial embolism was done by Tixier in 1907. In 1924, Leriche advocated the procedure as a means of preventing secondary thrombosis and of stimulating collateral circulation. This stimulated interest and numerous authors performed arteriectomies for this condition, especially in France. Haimovici (1937) collected reports of 17 arteriectomies with 12 successes (70 per cent). Success occurred most often in instances of

TABLE IV

ARTERIECTOMY FOR PERIPHERAL ARTERIAL EMBOLISM (FROM HAIMOVICI)

| ARTERY | ARTERIECTOMIES | SUCCESSES |
|---|---|---|
| Brachial | 4 | 4 |
| Popliteal | 3 | 2 |
| Femoral | 7 | 6 |
| External iliac | 2 | 0 |
| Internal iliac | 2 | 0 |

brachial, femoral, and popliteal embolism as shown in Table IV. After Leriche's championing of this procedure in 1924, between that date and 1934, successful cases were reported by Grégoire, Jouve, Langeron, R. Bernard, and Baillat. Gallavardin (1934) pointed out that an arteriectomy has two aims: to decrease sympathetic reflex stimuli and to prevent propagating thrombosis.

Leriche, Froment, and Vachon (1934) reported the case of a woman, aged 54 years, on whom they performed an arteriectomy for embolism of the femoral artery. This was done five hours after lodging of the embolus and was followed eighteen hours later by a novocain infiltration of the lumbar sympathetics on the same side. Ten days later the limb and its circulation were entirely normal. Ferey (1935) did an arteriectomy of the brachial artery at the same time as he performed an axillary embolectomy. The operations were performed thirty-two hours after the onset and all the clots could not be removed. Gangrene resulted and amputation was performed at the elbow.

Leriche, Froment, and Vachon (1934) listed the types of case in which they believed arteriectomy is indicated:

(1) Where, because of the condition of the patient, speed is essential.

(2) Where, on performing the embolectomy, the arterial wall is found to be damaged.

(3) In late cases seen after twenty-four hours.

(4) Where, after embolectomy and suture, there is secondary thrombosis. (It is quite possible that this last indication will seldom play a role now that heparin is utilized in most cases of embolectomy, vide infra.)

Jeanneney and Darget (1937) reported a case where embolectomy of the femoral artery was done but a new clot was found at a second operation twelve hours later. Because of this an arteriectomy was done with resultant gangrene and death. These authors point out that when arteriography reveals a paucity of collateral circulation, arteriectomy should not be done. Arteriectomy has also been advised by Leriche, Fontaine, and Dupertuis (1937) and by various pupils of Leriche.

One of these latter, Pamperi (1936) advised arteriectomy if the endothelium under the embolus appears damaged, if the operation is performed twenty-four or more hours after the embolism, or if gangrene

continues to threaten despite embolectomy. Arteriectomy has been less successful in the hands of Ferey (1935); Mathieu, Gérard-Marchant, and Lance (1935); Soupault (1935), and Schein (1935). While the words of Fontaine that "a good arteriectomy is better than a bad embolectomy" may be true, those of Griffiths that "a good embolectomy is best of all" are even truer. In general, Leriche will do embolectomies in patients seen early, but if postoperatively the pulsations disappear once more as evidence of rethrombosis, he reopens the wound and excises about 10 cm. of the vessel at the site of obstruction. Leriche (cited by Pampari) stated: "L'artériectomie est toujours suivie d'une vasodilatation active, avec hyperthermie dans le segment d'aval, à condition, évidemment, que les voies périphériques superficielles et profondes soient libres."

Grégoire (1939) also advised arteriectomy in peripheral arterial embolism. He based his preference for arteriectomy over embolectomy on the experience he had with a case of what he calls "useless embolectomy." An embolectomy was done for obstruction of the right femoral artery. Twenty-one days later the patient was able to walk, but pulsations below the operative site were extremely weak. To determine the cause of this, the artery was exposed for arteriography and it was found that throughout the length of Hunter's canal, the artery was completely occluded. Thus, despite the apparent success, the embolectomy was useless. Grégoire then postulated upon how many other cases reported as successes in the literature might not similarly be useless embolectomies. Some cases where necropsy or subsequent reoperation, such as those of Key, Nyström, Westerborn, and others, proved competency of the vessel following the first operation could not be doubted. Others, however, had no such proof. Because of this, Grégoire concluded:

"L'obstruction embolique des artères principales des membres doit être traitée par l'artériectomie. Cette opération évite la thrombose artérielle secondaire et le spasme des collatérales, de qui depend le pronostic."

Other advocates of arteriectomy include Schein (1935), DeTakats (1942) and Atlas (1942).

Not all the reports on this procedure, however, are favorable. While Leriche, Fontaine and Dupertuis (1937) reported excellent results following arteriectomy in a series of 78 cases (34 thromboangiitis obliterans, 33 arteriosclerosis, 6 traumatic, 3 embolus, and 2 syphilis) with only 19 total bad results, it is to be noted that in all three of the embolus cases results were bad. Thus, this article can be quoted as favoring arteriectomy in some cases, but not in embolus. Soupault (1935) found no benefit from iliac arteriectomy in his case. Mathieu, Gérard-Marchant, and Lance (1935) also had a failure after femoral arteriectomy.

In conclusion it may be stated that the two chief conditions for arteriectomy are (1) late cases (over twenty-four hours according to

Jeanneney and Darget [1937]—possibly longer when heparin is used), and (2) damaged arterial wall. When the collaterals are known to be poor, arteriectomy is often contraindicated. Arteriectomy should usually be performed so as to remove 10 cm. of vessel from the site of the exploratory arteriotomy down to, but not past, the next collateral. The value of arteriectomy is that it causes a peripheral vasodilatation if the collateral vessels remain intact as shown by Leriche, Fontaine, Grégoire and Jouve, Bernard, Carcassonne, and Jeanneney and Darget.

4. *Heparin.*—Heparin has been advised in the treatment of peripheral arterial embolism by several authors. In practically all instances such advice applies to the use of the drug in conjunction with surgical treatment rather than as a definitive mode of therapy in itself. Murray (1936) reported embolectomy performed on 17 patients in a series of 30 cases of peripheral arterial embolism seen at the Toronto General Hospital in the five-year period, 1931-1935. It is of interest that during this period there were 126 total cases of embolism distributed as follows: pulmonary, 56; cerebral, 35; central artery of retina, 3; coronary, 2; and peripheral arteries, 30. Of the 17 patients operated upon, 9, with 11 operations, were alive and well with adequate circulation to the extremity. Of the remaining 8, one was alive with amputation, while the others died. However, in all cases of death the circulation had been restored to the limb.

While Olovson (1938) did not use heparin in his cases, in discussing them in retrospect, he wondered if, as a prophylactic measure against secondary thrombus formation, heparin might not be of value. Olovson (1939) carried on experiments to test the efficacy of heparin (Jorpes) in treatment of arterial emboli. He suggested local use as well as general intravenous injection and also suggested that the suture materials be prepared with heparin. In experiments on dogs and rabbits, he found that a local hemostyptic would control local bleeding and prevent hematoma formation. In none of his experiments did a secondary thrombosis arise. Heanley (1939) administered heparin to his second patient, a man, aged 67 years, with femoral embolus due to auricular fibrillation. Ten thousand units were administered intravenously as soon as the artery had been closed and the embolectomy completed, and 45,000 units additional were given by continuous venoclysis over a period of three days. Despite this amount of heparin, gangrene occurred and amputation was performed fifteen days after embolectomy and four days before death. Fischer and Astrup (1939) showed that heparin is entirely inactive by mouth. Murray and Best (1938) reported the use of heparin in five embolectomies with four recoveries. Groth (1939) mentioned the use of heparin. Jorpes (1939) in his monograph on heparin reviewed its use in clinical and experimental instances of embolism. Mason (1939) wrote an American review of heparin at about the same time. The mechanism of action of

heparin has recently been reviewed by Ziff and Chargaff (1940). Groth (1940) was one of the first to use heparin in conjunction with embolectomy.

In the United States, the group of workers at the Henry Ford Hospital was among the first to use the newer heparin preparations clinically. The writings of McClure and Lam (1940), and Lam (1941, 1942) should be consulted as reporting the results of this group of workers. The mechanism of the action of heparin has recently been studied by Murray, Jaques, Perrett, and Best (1936), Lucia and Aggeler (1939), Fischer and Astrup (1939), Nyström (1939), and Ziff and Chargaff (1940). Heparin used clinically, is of five kinds: (1) That purified by Jorpes method and obtained from the Karolinska Institute, Stockholm, (2) "Vetren," a heparin solution marketed by Promonta Chemisches Fabrik, Hamburg, (3) heparin purified by the methods of Charles and Scott, and available from the Connaught Laboratories, Toronto, (4) heparin solution supplied by Hoffmann-LaRoche, Basle, Switzerland, and more recently (5) heparin prepared by several American firms. Heparin can be neutralized by protamine, 1 mg. of the latter neutralizing 0.3 mg. heparin in vitro or in vivo (Mason, 1939). However, this has little clinical application since protamine is toxic if administered in any form intravenously. Nyström (1936) used interrupted sutures in his embolectomy cases. He stopped any small spurting of blood with prolonged application of the gloved finger tip. Such technique is not applicable to heparinized patients and in general, in such instances, the arteriotomy wound is closed with a running silk suture. Dicumarol has little applicability to these cases since its delayed action makes it unfit for the emergency procedure of embolectomy.

Heparin has also been utilized by Bancroft (1940), Priestley, Essex, and Barker (1941), and by Lesser (1943). Bancroft and Glick (1941) reported the successful operation of embolectomy for a femoral embolus, 48 hours after onset of symptoms, by the use of a retrograde suction procedure. They further attributed the success of the operation to the combined use of heparin and pavaex treatment. Lindgren (1939) used heparin successfully in two cases, advising 0.5 per cent thionin locally in the wound to counteract the heparin effect. Ravdin and Wood (1941) used heparin in conjunction with their successful aortic embolectomy. Marshall and Vary (1942) reported the successful use of heparin in conjunction with embolectomy for removal of an embolus of the external iliac artery.

One of the chief advocates of the use of heparin in conjunction with embolectomy has been Murray of Toronto. In 1940, this author stated that the results following embolectomy with heparin were better in his experience than those following the use of the pavaex boot. Murray (1940) performed experiments on dogs to test the effects of heparin in embolectomy. Peripheral vessels in dogs were plugged with foreign

bodies and blood clot and closed. The plugs were removed after intervals up to seventy-two hours. In the earlier hours removal was easy, but later involved scraping off from the intima, usually followed by recurrent thrombosis. Heparinization, however, prevented this secondary obstruction and specimens removed a month later showed the artery to be clear of thrombi. In twelve clinical cases the vessel remained patent in all after embolectomy with heparin and the circulation to the extremities was maintained. Two patients died at intervals after operation and necropsy showed the vessels at the site of incision to be quite patent. Since one of these two patients who died had had the embolectomy done twenty-five hours after onset, this necropsy finding is all the more remarkable.

Murray (1940), in reviewing his experience with heparin, reported twelve peripheral arterial embolectomies performed successfully with the aid of heparin. He stated, "If the lumen was completely cleared of the plug and the circulation restored, all the cases were successful when treated with heparin." He introduced the drug into the vessel at the time of operation and heparinized the patients from three to fourteen days postoperatively. One of his patients showed a residual anesthesia and loss of motion of the foot somewhat similar to that in our Case 12. Two patients died later and necropsy revealed that the arterial channels were quite patent. This patient of Murray's was treated twenty-five hours after onset of symptoms of obstruction of both common iliac arteries. Murray concluded regarding embolectomy: "From our experiences with the use of heparin in this operation, one is encouraged to believe that many more cases may be saved amputations." In Murray's last available complete report (1941) he described the use of heparin in conjunction with embolectomy in twenty-six cases.

The series of articles in the Acta Medica Scandinavica, volume 107, 1941, page 107, et seq., shoud be consulted. In the opening article of the discussion, Jorpes discussed the general aspects of the situation. Lindgren and Wilander considered the use of heparin in vascular surgery. These authors reported the results of eight embolectomies done in conjunction with heparin on seven patients. One of the patients presented a bilateral popliteal embolism of four and one-half days' duration with a successful result on one side, but failure on the other. Rosenqvist's discussion on the usefulness of heparin in combating arterial embolism and thrombotic complications discusses mainly the question of pulmonary embolism.

Several of our own cases have been reported elsewhere in this communication, but the following examples are cited at this point.

CASE 5.—G. L., a man, aged 62 years, suffered from arteriosclerotic heart disease and auricular fibrillation since 1937 or before, and myocardial failure since June, 1938. In January, 1939, he had an infarction of the right lung. He was admitted to the hospital on Oct. 23, 1939, again for observation because of myocardial failure. On November 4, he developed acute obstruction of the central artery of the

left retina. Two days later on Nov. 6, 1939, at 8 A.M. he developed sudden pain in the left leg below the knee with blanching and coldness. Intravenous heparin by constant drip was given both before operation and for five days postoperatively. After operation the patient was placed on the oscillating bed.

*Operation.*—This was done by the senior author (R. D. McC.), at 11 A.M., three hours after lodging of the embolus. Local anesthesia supported by a little open drop ether was used to make a 10 cm. vertical incision over the patient's left popliteal space. The popliteal artery was separated from the vein. Pulsation could be felt in the upper portion of the artery, but not below. All of the vessels were very sclerotic. A longitudinal incision was made in the artery and a partially organized nonadherent clot 4 cm. in length was removed. A bulldog clamp was then placed on the artery above the incision to prevent bleeding.

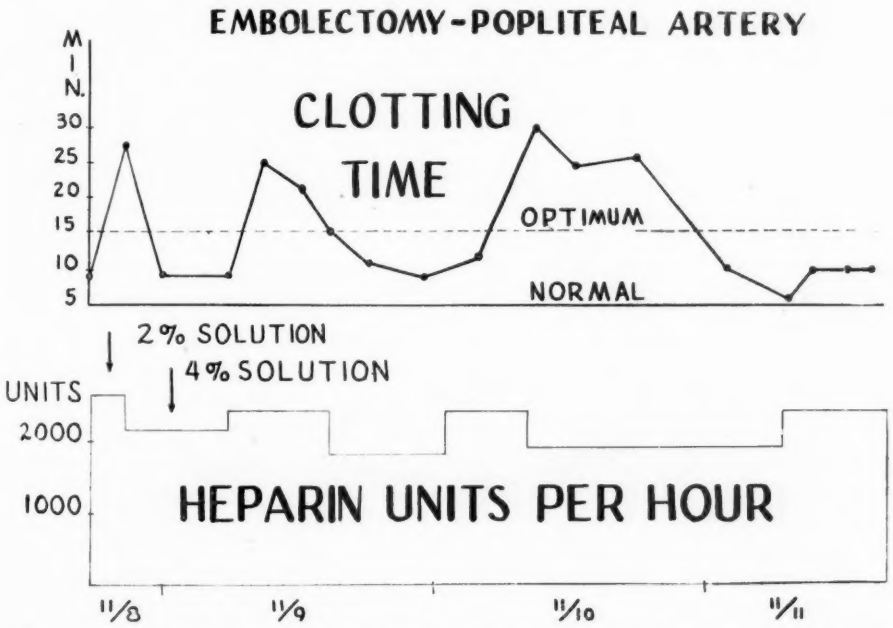


Fig. 3.—Heparin chart of G. L., Case 5. (We are indebted to Dr. C. R. Lam for preparation of this chart.)

Closure of the arteriotomy wound was effected by a continuous suture of fine silk which was reinforced with another continuous suture in the opposite direction. When this was done, the bulldog clamp was removed and the pulsation returned to the vessel throughout its length. There was practically no oozing of blood along the suture line. The superficial wound was closed. It should be noted that this operation was done with the patient under the influence of heparin. This is the only one of our cases in which heparin was used preoperatively as well as postoperatively.

The pulsations in the arteries in both feet were normal after operation and remained so. The patient developed another pulmonary infarct on the tenth postoperative day, but was able to get out of bed on Nov. 27, 1939. He was discharged from the hospital on Dec. 14, 1939, with complete restitution of circulation in the affected leg. He died of cerebral embolism on Nov. 26, 1940, a little over a year after operation. Just prior to death examination showed a normal circulation and function of both legs.

The prompt diagnosis, early treatment, and complete removal of the embolus with the help of heparin led to a good result in this case. The embolectomy gave this patient over a year additional life with entirely normal extremities (see Fig. 3).

CASE 6.—H. Br., a woman, aged 68 years, had a history of arteriosclerotic heart disease, arterial hypertension, and angina pectoris. On Oct. 8, 1941, she had a sudden attack of precordial pain followed in one hour by pain in the left calf with coldness and pallor. A diagnosis of embolism of the left femoral artery was made and operation performed fourteen hours after the accident.

*Operation* (H. N. H.).—The patient was turned on the right side with the left side up, and opposite the second and third lumbar vertebral spine, an injection of 10 c.c. of novocaine was made two fingerbreaths lateral to the left side of the midline, and two fingerbreadths deep to the transverse processes, thus attempting to infiltrate the sympathetic chain at this site. There was a slight temperature response in the leg, indicating that the novocain went to the right place but the result was not striking. The patient was then placed again on her back and a vertical incision four inches long was made over the fossa ovalis. The femoral artery was exposed and opened. A small clot was brought out from the distal end. The wall of the artery was thickened, so as to be almost as thick as its lumen and somewhat irregular. There were, however, no ulcerations or incrustations on the lining. After removal of the small clots from the distal end, a very weak flow of blood came from it. There was no flow of blood from the proximal end and there was no pulsation in the artery except as palpated by placing the finger high up near the bifurcation of the femoral. A probe and later a catheter were inserted into the artery. Both of these brought out practically no clots, so with finger milking, placing the finger up beneath Poupart's ligament as high as we could reach, we milked out four portions of clot. These evidently came from the bifurcation of the femoral artery.

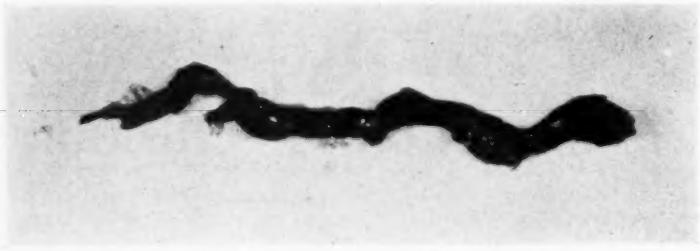

Fig. 4.—Emboli from left common femoral artery of H. Br., Case 6.

Following this, there was a free gush of pulsating blood with perfect freeing of the artery and 1 c.c. of heparin solution was injected into the distal segment of the artery. A double row of lock suture with arterial silk was then made using one suture and reversing it back on itself. Following this, there was a slight pulsation in the artery distal to the point of suture. We injected 6 c.c. total additional heparin in three doses into the artery by means of a hypodermic syringe and needle. When we compressed the vessel, about one and one-half inch below the line of suture, blood leaked out at the site of the suture more easily. Thus, although there was no definite pulsation below the line of suture, there was evidently a moderate flow, so that it was estimated that we had restored the circulation to one-third its correct amount. More heparin was now injected. Further restoration was impossible because of the markedly constricted and sclerotic nature of the vessel. We had now exposed the distal one-half inch of the vessel at the lower end, to be sure that there was not a distal clot.

The wound was then closed in several layers of interrupted silk. A rather loose elastoplast bandage was applied. The patient was to be continuously heparinized. During the operation she received a total of 10 c.c. of heparin into the artery.

There was no improvement in the condition of the left leg and the patient's cardiac condition grew worse. On the seventh day after operation, the patient developed an embolism of the right leg and died the day after.

Lam prepared the following notes on four of our cases which received heparin and which are described in detail elsewhere in this paper.

CASE 4.—(J. L.).—Continuous heparin begun at 2:15 P.M. Initial clotting time was 3 min. 15 sec. Given 2 vials of heparin before death. Highest (longest) clotting time obtained was 5 min. at 11:00 P.M.

CASE 5 (G. L.).—Reported in detail in the article by McClure and Lam in J. A. M. A., May 25, 1940. Necessary to discontinue heparin on account of congestive failure, and aggravation of symptoms from salt solution given intravenously. However, if more heparin had been urgent, we could have given it undiluted by the intermittent method. (See Fig. 3.)

CASE 9 (E. B.).—Attempted embolectomy for embolus in left external iliac artery. This patient was heparinized immediately after the artery was sutured, by the injection of 3 c.c. of heparin, followed by continuous heparin by cannula in the right leg. Given 6 vials of Connaught heparin, 1,500 units per hour necessary to maintain the clotting time at the optimum level.

CASE 12 (G. G.).—Heparinized immediately after operation. Given 16 vials of Connaught heparin over a period of four days, about 1,500 units per hour necessary to maintain the clotting time, at the optimum level. Necessary to discontinue on account of bleeding from popliteal wound (see Fig. 7).

5. *Papaverine and Related Drugs.*—Papaverine, introduced by Pal (1914), was first used as an agent to relax arterial spasm in cases of arterial embolism by Denk (1934) of Vienna. Henschen (1935) used the drug in similar cases intravenously. Denk (1936) reported remarkable results from the intravenous injection of eupaverin (a European Merck trade name for papaverine). In a series of ten of Denk's own cases of embolism of the extremities treated with this drug, 7 patients were cured, 2 died, and 1 required amputation.

Papaverine, an alkaloid of the opium group, was first advocated as a means of relieving smooth muscle spasm by Pal of Vienna in 1914. The chief pharmacologic effects of papaverine are peripheral and it relaxes all types of smooth muscle without paralyzing them. Its analgesic effect is such that when given subcutaneously, about 40 mg. corresponds to 10 mg. of morphine. Papaverine hydrochloride in ½ gr. (0.03 Gm.) doses or sodium nitrite in 1 gr. (0.06 Gm.) doses given intravenously will affect the general blood pressure little or none at all, but will enlarge the venocapillary portion of the vascular bed. This acts as a general peripheral vasodilator. The clot itself is probably not affected, but the peripheral circulation may be. Papaverine is an agent producing a direct effect on the smooth muscles in the vascular wall and has no remote effect conveyed by the nerves. It is difficult to see how it can reach the affected vessel when the factors of the embolus itself, postembolic thrombosis, occlusion of collaterals, collapse of the

artery because of drop in pressure, and reflex spasm all contribute to blocking off its access. Åkesson (1937) showed that intravenous eupaverin does not prevent secondary thrombosis, while Groth (1939) showed that direct intra-arterial injections were also ineffective in this regard. Groth (1939) and Lund (1939) believe that "the prospects of obtaining any kind of effect on the arteries by intravenous injections of eupaverine are thus nonexistent or in any case very small" (Groth) and the results of papaverine are "possibly not much better than the results of no treatment at all" (Lund).

DeTakats (1936) reported on the beneficial effects of intravenous papaverine in a case of pulmonary embolism, another of acute peripheral thrombosis, and three cases of peripheral arterial embolism. Geisthövel (1938) advised eupaverine in cases of arterial embolism, but only as an adjunct to operation if the circulation was not promptly restored. He advised its use not only intravenously, but locally in the involved vessel. Funck-Brentano (1938) advised 0.25 Gm. of papaverine (either intramuscularly or intravenously) and acetylcholine (0.1 Gm. intravenously or 0.4 Gm. intramuscularly) every 30 minutes for five to six hours. Funck-Brentano (1938) also believed that medical treatment of the vascular spasm doesn't take sufficient account of the action of the embolus as a starting point of thrombosis. He stated in this regard: "La thérapeutique par action à distance (chirurgicale, anesthésique ou médicale) nous paraît devoir être une action d'accompagnement et non pas une action isolée." Funck-Brentano (1938) concluded in this regard: "Le traitement médical doit demeurer, actuellement, un adjuvant de la chirurgie."

Other drugs have been used to accomplish much the same purpose. Funck-Brentano (1938) mentioned the use of yohimbine (a sympatholytic drug).

Perlow (1940) reported slight improvement in one case of embolism of the iliac artery first treated four days after lodging of the embolus with prostigmine (the dimethyl carbamic ester of m-oxyphenyltrimethylammonium methylsulfate). This same author reported improvement in another case of peripheral arterial embolism following the use of prostigmine. Villaret and Justin-Besançon (1926) first used acetylcholine in the treatment of arterial embolism, using 0.2 to 0.4 Gm. subcutaneously every thirty minutes for five or six doses. Ferey (1935) and Grégoire (1939) used acetylcholine, while Henschen (1935) used acetylcholine in the wound.

Funck-Brentano (1938) stated: "Papavérine et acétylcholine agissent de deux façons differentes et leur association réalise des effets plus puissants que ceux, qu'on peut obtenir par l'emploi isolé de l'un d'entre eux." Atropine is contraindicated because it suppresses completely the action of acetylcholine.

The route of administration may also be changed, Östling (1939) reporting a favorable result following the use of eupaverin injected

into the affected artery after embolectomy. No postembolic thrombosis occurred in his case.

In our own series papaverine was used in several instances, but as other treatments were used at the same time, no conclusions as to its efficacy can be drawn.

6. *Alternating Positive and Negative Pressure (Pavaex).*—The use of this method of treatment, either definitively, or in conjunction with other forms of therapy, was early popularized by Reid and Herrmann (1933). Conway (1936) reported good results in several cases of embolism of the extremities with the use of pavaex. Burnett (1939) also found the method to be efficacious. Collens and Wilensky (1937) reported favorably on the use of intermittent venous occlusion in the treatment of three cases of peripheral arterial embolism. Linton (1937) advised embolectomy followed by pavaex as the best method of treatment. Edwards (1937) presented a modified pavaex boot for management of acute arterial obstruction. Herrmann (1936) reported on 7 patients with embolic obstruction of the extremities treated by the pavaex boot with 6 good results. Graham (1937) reported improvement in 6 out of 9 patients treated with a pavaex boot. He tended to favor conservative measures, especially after ten hours. Ravdin and Wood (1941) used pavaex in conjunction with embolectomy. Linton (1943) found that intermittent venous occlusion was effective in treating a case of traumatic thrombosis of the left external iliac artery. In this author's previous paper (1937) his good results with the pavaex treatment are all the more noteworthy when it is observed that in 2 cases the embolus was at the aortic bifurcation, 1 was in the common iliac and 2 in the popliteal artery, all notoriously difficult locations.

Not all articles on the subject are favorable to this form of therapy. DeTakats (1934) wrote a preliminary report on the treatment of obliterative vascular disease with alternating negative and positive pressures. However, DeTakats (1936) reported little or no improvement in a series of 4 cases of peripheral arterial embolism treated with the pavaex boot. In another article in the same year, he found that the pavaex boot was not nearly as efficacious as papaverine in the treatment of embolic obstruction of the extremities. The next year, however, DeTakats (1937) used intermittent venous hyperemia in the treatment of one case of postembolic arterial occlusion. Pickrell (1943) opposed the use of the pavaex apparatus in peripheral arterial embolism. Wilson and Roome (1936) used the pavaex boot on three patients with leg embolism with one good result. The improved patient as well as one of the two with poor results received papaverine in addition. Because of the small amount of pavaex treatment given in the successful case, these authors believed that it could not account for all the improvement. No large series of cases treated by a machine

have been presented to date in which the results will at all compare with those of surgical operation. Even where gangrene is averted, the limb in many cases is permanently impaired. Reviewing the subject of embolectomy in a recent editorial, Lund (1939) stated that he questioned the value of papaverine and thought that operation was better than the pavaex boot. In late cases, however, he believed operation to be contraindicated and the pavaex treatment the method of choice.

7. *Amputation.*—In most instances a primary amputation is not advised because in even the most serious cases a trial with medical management is advisable. In general, all definitely gangrenous cases eventually come to amputation as do those first seen after too long a period since lodging of the embolus. This period may be extended somewhat by the use of heparin, but certainly the statement of DeTakats (1936) that amputation is indicated after forty-eight hours still holds true in the main. Reports of two cases in which unsuccessful embolectomy was followed by amputation are listed here.

CASE 7.—A. S., a man, aged 50 years, with arteriosclerosis and arteriosclerotic heart disease, had a sudden onset of pain in the right leg with absent pulses, pallor, and coldness. A diagnosis of right iliac embolism was made and operation performed nine hours after the accident.

*Operation* (H. N. H.).—A right oblique incision just below the inguinal crease was made, exposing the right femoral artery. While the artery was of normal size, it had no palpable pulsation. A longitudinal 1 cm. arteriotomy incision was made revealing a slow stream of blood coming from both directions, but while there was a very slight pulsation from above, there was none below. Probing downward for a distance of 30 cm. and upward for about the same distance with both a catheter and a probe, revealed no obstruction. Upon sucking the catheter out several times vigorously from the upper segment, the blood flow seemed to be markedly improved but was still far from normal. We could do no more. After closing the arteriotomy wound with a double row of continuous fine arterial silk, 5 c.c. of heparin were injected into the artery. There was no leakage and the superficial wound was closed. The leg was not warmer after the operation.

A midthigh amputation was done eight days after the first operation, and the patient was discharged from the hospital two months later.

CASE 8.—G. McC., aged 62 years, had a history of generalized arteriosclerosis and old coronary occlusion. One week before admission he had another coronary attack and on May 15, 1942 he was admitted thirteen hours after a sudden attack of pain, numbness, and coldness in the left foot. Examination revealed pallor and loss of sensation of the left leg below the calf and absence of all pulsations of the left leg including the femoral. A diagnosis of left iliac embolism was made and operation performed sixteen hours after the accident.

*Operation* (H. N. H.).—A left paravertebral novocain injection was done with no marked effect. Palpable pulsation remained absent in the left external iliac artery and in the vessels below. The femoral artery was exposed through an oblique incision below the inguinal crease. The artery was pulseless. A 1 cm. longitudinal arteriotomy opening was made revealing no retrograde pulsation, a very slight retrograde ooze, and no ooze or pulsation from the proximal end. A blunt probe was inserted upward for a considerable distance meeting no obstruction, but on removing it a soft thrombus about 1 by 0.5 cm. was removed. This improved the proximal

flow only slightly, but did not affect the retrograde flow at all. Probing, aspiration, and injection of saline solution with a catheter were all performed to no avail, so finally the arteriotomy wound was closed with continuous fine white Chinese silk, following which 3 c.c. of heparin were injected into the artery and the superficial wound was closed. There was no improvement in the pulse or temperature in the foot or leg after operation.

Left midthigh amputation was performed on May 19, 1942, four days after the first operation, and the patient got along well until September 26, 1942, when he died of a cerebral embolism.

8. *Embolectomy.*—This is discussed in detail after a consideration of the technique.

### TECHNIQUE OF EMBOLECTOMY

Certain aspects of the technique will be considered in the individual case reports, but a general discussion of the subject will be made at this time. The importance of the collateral vessels is shown in Table V.

Henschen, of Basle (1935), has several suggestions for the technique of embolectomy: (1) For indirect retrograde embolectomy he uses a long corkscrew tipped probe, (2) for the same purpose he inserts a catheter with its opening at the end and applies suction from an electrically driven suction pump, (3) peripheral irrigation of the vessels at the end of the operation with 10 to 15 c.c. thorotrast or 20 c.c. equal parts normal salt solution and uroselectan for the combined purpose of arteriography and flushing out the vascular periphery, and (4) avoidance of all tight bandages after operation.

TABLE V

SUPERIOR LIMIT OF CIRCULATORY DISTURBANCE IN PERIPHERAL ARTERIAL EMBOLISM

| SITE OF EMBOLUS | AUTHOR | | |
|---|---|---|---|
| | SENCERT | KEY | BULL |
| Aorta | Crural arcade | Crural arcade and abdomen up to the umbilicus | Crural arcade |
| Common iliac | Crural arcade | Middle of the thigh or at the arcade | Crural arcade |
| Common femoral | Inferior third of the thigh | Inferior third of the thigh, at the knee, or just below the knee | Inferior third of the leg |
| Popliteal | Inferior third of the leg | Superior third or between the middle and superior thirds of the leg | Instep or inferior third of the leg |

*Anesthesia.*—Local anesthesia is favored by most authors. Embolectomy patients are often severely ill and furthermore the operation is usually readily carried out under local anesthesia. Danzis (1933), Leriche, Froment, and Vachon (1934), Henschen (1935), Haimovici (1937), and Groth (1940) are among the many advocating this type of anesthesia. Danzis (1934) advised regional or block anesthesia. Deitch (1936) used spinal, but Fontaine opposed spinal anesthesia as the method of anesthesia in embolectomy because the resultant hypotension and local stasis impair still further the already diminished circulation.

On the other hand, Koucky, Beck, and Hoffman (1940) used spinal anesthesia. Edwards (1938), in operating on three patients with embolism of the arm, with two good local results used local brachial plexus block anesthesia in all three cases.

*Site of Arteriotomy.*—A longitudinal arteriotomy incision slightly distal to the location of the embolus is most frequently advised and was used by Carling (1934), Jefferson (1934), Heanley (1939), Groth (1939), and by the present authors. Haimovici (1937) opposed retrograde embolectomy, while Deitch (1936) opened the popliteal artery in one of his patients, only to find a femoral incision necessary. Another advantage of opening below the obstruction, however, is that if any accident occurs, the obstruction will be as low as possible. Concerning the site of arteriotomy, Bernard counseled: "de ne pas artériotomiser un trone qui donne les branches importantes au niveau de ces branches, mais au-dessous d'elles: si la suture donne lieu à une oblitération secondaire, les branches en question auront néanmoins des chances de rétablir la circulation du membre." Girdlestone (1935) exposed the common femoral artery, but while palpating it the pulsations in it as well as in the posterior tibial suddenly returned, so he assumed he had fortunately pushed the embolus into the profunda femoris. Jefferson (1934) also advised "a deliberate attempt to massage the clot into the subsidiary branch. If this failed the operation would be proceeded with on normal lines and the artery opened."

*Removal of Embolus.*—Various instruments, including alligator forceps, Babcock's vein probes, uterine sounds, ureteral catheters, small urethral catheters, and Merke's corkscrew probes have been used to remove the emboli. In 1894, Severeanu suggested that in cases of amputation for gangrene due to arterial obstruction, a bougie might be passed up for some distance from the cut surface of the stump into the divided proximal end of the main artery so as to insure its patency, to remove clots, and to minimize the risk of gangrene of the flaps. Andrews and Harkins (1932) used a large urethral catheter for its plunger action to pull out an embolus from the femoral artery. Murphy first used retrograde sounding. Mason and Hurxthal (1928) used a No. 10 catheter to flush out the vessel with sodium citrate solution *after* removal of the embolus. Allen (1929) advised the use of a flexible spiral instrument. Stevenson (1938) and Stevenson and Walker (1938) developed a special needle for arterial embolectomy. This needle is ten inches long and has a ball on the end one-fourth inch in diameter. It is used for probing arteries for emboli.

*Closure of Wound.*—Mason and Hurxthal (1928) emphasized the need for suturing intima to intima. Jefferson (1934) and Carling (1934) stated that they did not believe it mattered much if the sutures presented a little on the inside of the vessel. Banks (1934) and others advised interrupted sutures, but since the introduction of heparin, a running stitch has been found preferable.

*Anticoagulants.*—The use of heparin (discussed in detail elsewhere in this communication) is popular at present. Key (1922) used vaseline coated instruments and irrigation of the wound with 2 per cent sodium citrate. Henschen (1935) and others also advised sodium citrate.

*Arteriography.*—Leriche, Froment, and Vachon (1934) advised arteriography to locate the embolus.

*Concomitant Ligation of Veins.*—Ligation was advised by Makins (1922) and other authors, but not by Gage and Ochsner (1940). Larks (1934) suggested ligature of the accompanying vein in cases done too late for an embolectomy. On the whole this procedure has not been widely adopted.

*Repeated Embolectomy.*—In some cases reoperation may be necessary and good results may follow even after several trials. Harkins (1934) reported two attempts at embolectomy on the same patient, once on the left arm and once on the left leg. Groth (1936) collected 6 cases of re-embolectomy at the same site including one patient of his own with 4 separate embolectomies, 2 at the same site. Deitch (1936) also reported an example of multiple embolectomy. A man, aged 44 years, had an embolus removed from the left common femoral artery in January, 1934, and one from both the right common femoral and left common iliac in December, 1935, with success in all three instances. Lindgren and Wilander (1941) did a bilateral popliteal embolectomy, successful on one side, but requiring amputation on the other. MacFarlane (1940) reported a case of multiple operations.

*Miscellaneous Procedures.*—Funck-Brentano (1938) discussed the use of thrombotripsy. Neuhof's technique (1932) of intentional partial arterial occlusion as an adjunct to embolectomy was not adopted by other surgeons. Haimovici (1937) pointed out the advantage of noticing after an embolectomy if blood comes from the distal end of the opened vessel. Embolectomy with ligature was suggested by Finch (1934), but Haimovici (1937) points out that arteriectomy is better. Heidrich (1921) reported a 100 per cent mortality after ligation of the common iliac artery. Anastomoses with venous grafts were attempted by Stewart (1907), but the newer methods of arterial anastomosis recently described by Blakemore, Lord, and Stefko (1943) using vitallium tubes offer more promise where such a procedure is indicated.

Nyström (1936) advised the use of rubber tubes for hemostasis rather than rubber-shod clamps. If a reflux of blood occurs when the distal tubes are released, then they are again held taut and the suturing of the incision is begun. At this time, Nyström used interrupted sutures. He did not believe that intima-to-intima approximation was necessary because it may further narrow the lumen. He used bulbous tipped probes for retrograde embolectomy, performing what he called "intra-arterial sweeping." Extreme gentleness is advised at all times.

REPORTED CASES OF EMBOLECTOMY

The operation of peripheral arterial embolectomy has been especially practiced in the Scandinavian countries, but has also been done in Great Britain and in the United States quite frequently. Mason and Hurxthal (1928) reported 5 cases of femoral embolectomy. In all instances the embolus lay where the profunda branched off from the common femoral artery. Allen (1929) reported 6 embolectomies in 7 attempts, with one good result. In 1933, Pearse made a statistical study of 286 peripheral embolectomies reported in the literature. He found the time of operation after onset to be of great importance, improvement occurring in 40 per cent of cases following operation performed during the first ten hours, 14 per cent in the second ten hours, and 8 per cent in the third ten hours. Jefferson (1934) reported 6 personal cases, 2 completely successful (1 arm, 1 leg), 2 partly successful (both arm) and 2 unsuccessful (1 arm, 1 leg). Valdoni (1935) collected 333 cases from the literature.

Dissatisfaction with the operation of embolectomy is especially noted in the American literature (Graham [1937], DeTakats [1936], and others). This is largely and justifiably based upon the frequent failures and many postoperative deaths. Strömbeck (1935) reviewed 327 operations following which 63 per cent of the patients died in the hospital and only 12 per cent survived for five years. Danzis (1933) reported that only 41 per cent of reported embolectomies were successful and that one-quarter of these successful ones died in the hospital. Mason and Hurxthal (1928), Allen (1929), and other reporters of small series gave similar pessimistic results. DeTakats (1936) reported 5 embolectomies with 2 good results, both of which were iliac obstructions. Two of the other patients died of other emboli.

In Sweden, Key was able to report, in 1936, that he had personally done 32 embolectomies in 30 cases. At the Maria Hospital, Stockholm, on his service, and in his own private practice, 48 embolectomies were performed on 43 patients, there being an embolus in both legs in 5 cases. Nyström (1936) reported 39 embolectomies done on 35 patients at his clinic in Uppsala (1922-1934). It is of interest that 50 per cent of these went home with restored circulation. The most frequently involved sites of operated embolism of the extremities according to Nyström's collection of 382 Swedish cases are: femoral (54.5 per cent), iliac (17.3 per cent), axillary and brachial (11.8 per cent), and popliteal (11.3 per cent) (see Table VI). Strömbeck's (1935-1936) summary of the late results of 327 peripheral embolectomies performed in Sweden is noteworthy. Of these, 63 per cent died in the hospital, 18 per cent were discharged improved after amputation, and 19 per cent had good circulation on discharge. Of these latter, three-fourths remained alive after one year, one-half after three years, one-third after five years, and one-eighth after ten years. Strömbeck reiterated what

TABLE VI

RESULTS OF EMBOLECTOMY IN 382 SWEDISH CASES (NYSTRÖM)

| SITE | DISCHARGED SURVIVING | | | | DIED IN HOSPITAL | | TOTAL |
|---|---|---|---|---|---|---|---|
| | WITH RESTORED CIRCULATION | | AFTER AMPUTATION | | | | |
| | NO. | PER CENT | NO. | PER CENT | NO. | PER CENT | |
| Axillary artery } Brachial artery } | 20 | 44.4 | 9 | 20.0 | 16 | 35.5 | 45 |
| Ulnar artery | -- | -- | -- | -- | 1 | -- | 1 |
| Aortic bifurcation | 3 | 17.7 | -- | -- | 14 | 82.3 | 17 |
| Iliac artery | 10 | 15.1 | 13 | 19.7 | 43 | 65.2 | 66 |
| Femoral artery | 43 | 20.7 | 32 | 15.4 | 133 | 63.9 | 208 |
| Popliteal artery | 9 | 20.9 | 14 | 32.6 | 20 | 46.5 | 43 |
| Tibial artery | 1 | -- | 1 | -- | -- | -- | 2 |
| Total | 86 | 22.5 | 69 | 18.1 | 227 | 59.4 | 382 |

has been pointed out before that this short survival period is accounted for by three factors: age of the patients, character of the underlying cardiac condition, and tendency to develop new embolisms. Hindmarsh and Sandberg (1936) summarized 45 embolectomies performed in Einar Key's Clinic on 40 patients from 1912 to 1934. The majority (77 per cent) were suffering from heart disease. The local object of the operation was attained 23 times (51 per cent) and of these, 17 (38 per cent) were discharged alive. Of the remaining patients, 10 were discharged alive despite amputation. Olovson (1938) reported 8 peripheral arterial embolectomies. In 3 brachial operations success was attained in 2, while in the third amputation was required with resultant death. Four femoral embolectomies gave 2 good results and 2 deaths from general causes. One popliteal embolectomy was followed by death in ten days from cerebral embolism. Thus, in this series, in 5 patients circulation was restored (62 per cent) and 4 patients were discharged from the hospital free from symptoms (50 per cent). Results in other Swedish cases are shown in Table VII.

In this country, Linton (1937) reported 44 cases of acute arterial occlusion (40 emboli and 4 thrombi) in 36 patients seen at the Massachusetts General Hospital, including 1 case reported by Allen in 1929. Only 67 per cent of 30 of these cases of acute arterial obstruction studied by Linton (1937) gave a history of sudden severe pain in the patient. This agreed with the statistics of McKechnie and Allen (1935), who found that pain was the initial symptom in only 54 per cent of the cases they studied. In this series, 12 embolectomies in eight years (including one of Allen, reported in 1929) were performed with 4 recoveries. Fifteen patients were treated by pavaex with 9 recoveries.

Griffiths (1940) reported that from 1925 to 1940, he and Jefferson had seen 21 patients with 27 peripheral emboli within forty-eight hours of onset of symptoms. On 16 of these patients, 20 embolectomies were performed. The results included 8 complete failures (postoperative gangrene or death), 1 incomplete failure (limited gangrene), and 11

TABLE VII

RESULTS OF PERIPHERAL EMBOLECTOMY*

| AUTHORS | NUMBER OF CASES | | | | MORTALITY PERCENTAGE | PERCENTAGE OF SUCCESS |
|---|---|---|---|---|---|---|
| | DISCHARGED ALIVE | | DIED IN HOSPITAL | TOTAL | | |
| | WITH GOOD CIRCULATION | AFTER AMPUTATION | | | | |
| Swedish cases, except Key (1935) | 61 | 59 | 207 | 327 | 63 | 19 |
| Key (1935) | 17 | 10 | 18 | 45 | 40 | 38 |
| Lund (1937) | 10 | 5 | 12 | 27 | 44 | 37 |

*Classification as in Papers in Acta Chirurgica Scandinavica, 1935.

successes (complete restoration of circulation). The successes included 4 instances of upper limb embolism, the same number of lower limb embolisms, and 3 instances of successful aortic embolectomy.

In their review of 25 patients with peripheral arterial embolism seen at the Cook County Hospital from 1928 to 1938, Koucky, Beck and Hoffman (1940) reported 3 embolectomies with 3 deaths. One of these was a femoral embolectomy while the other two were emboli at the aortic bifurcation, with transperitoneal embolectomies. One of these latter 2 patients lived forty-two hours despite continued gangrene of the legs, while the other lived thirty-six hours with pulse return in one day. Murray (1941) reported 26 embolectomies done in conjunction with the use of heparin. Of Pratt's (1942) series of 12 embolectomies, 5 survived, a mortality of 41.6 per cent. Dickinson (1942) presented 6 cases of embolectomy with 1 recovery, that in an instance of embolism of the common iliac artery.

TABLE VIII

COLLECTED CASES OF PERIPHERAL ARTERIAL EMBOLECTOMY

| AUTHOR | NO. OF CASES |
|---|---|
| Key (1922) | 45 |
| Jefferson (1925) | 73 |
| Petitpierre (1928) | 118 |
| Key (1929) | 216 |
| Andrews and Harkins (1932) | 268 |
| Pearse (1933) | 286 |
| Valdoni (1935) | 333 |
| Strömbeck (1935)* | 327 |
| Nyström (1936)* | 382 |
| Groth (1936) | 535 |
| McClure and Harkins (1943)† | 690 |

*Swedish cases only.

†Groth's collection plus: Murray (1941), 26 cases; Lund (1937), 25 cases; Griffiths (1940), 14 cases (20 less 6 reported by Jefferson in 1934); Pratt (1942), 12 cases; Graham (1937), 10 cases; Olovson (1938), 8 cases; Lindgren and Wilander (1941), 8 cases; McClure and Harkins (1943), 6 cases; Dickinson (1942), 6 cases; DeTakats (1936), 5 cases; Linton (1937), 4 cases; Lesser (1943), 4 cases; 3 cases each by Collens and Wilensky (1937), Koucky, Beck, and Hoffman (1940), and Edwards (1938); 2 cases by Heanley (1939); and single cases by Blackburne (1938), Wardle (1938), Duncan (1938), Stevenson (1938), Burnett (1939), McMaster (1939), Tanner and Cleland (1940), Hughes and Berry (1940), Groth (1940), MacFarlane (1940), Bancroft and Glick (1941), Brunkow (1941), Marshall and Vary (1942), and McGhie (1942).

Additional cases collected from the literature by Fiolle and Funck-Brentano (1937) may not be included.

Successful femoral cases were reported by Blackburne (1938) and Wardle (1938). A successful popliteal case was reported by Duncan (1938). Larks (1934), Brunkow (1941), and McGhie (1942) also reported a successful case. Single cases were described by Banks (1934) and Scott (1934) while Zierold (1933) reported 11 cases, and Lesser (1943) described 4 cases. Sheen (1934) reported a case of bilateral embolectomy of the femoral arteries. Tanner and Cleland (1940) reported a successful axillary embolectomy in a woman aged 57 years. These authors used no heparin.

The largest collected series is that of Groth (1936) who gathered 535 cases of peripheral arterial embolectomy from the literature. In 1939, Groth reported that 46 embolectomies were performed at the surgical clinic in Uppsala from 1922 to 1939. Our own collected series numbers 690 and is based on Groth's collection as shown in Table VIII.

Several of our own case reports follow.

CASE 9.—E. B., a man, aged 59 years, had known arteriosclerosis and auricular fibrillation. On the morning of April 20, 1940, he developed sudden pain in the abdomen, followed shortly thereafter by localization in the left leg and hip. He was brought to the hospital. Examination revealed an absent left femoral pulse and sensory loss below the inguinal ligament on the left side. A diagnosis of embolus of the left iliac artery was made and embolectomy was performed under local anesthesia by another surgeon ten hours after lodging of the embolus. No sympathetic block was used, but heparin was given postoperatively.

*Operation.*—The common femoral artery was exposed just at the point of division into the superficial and deep branches. The embolus lay at the bifurcation and extended down into the superficial femoral, but the deep femoral was free. The common femoral was better exposed by incising Poupart's ligament and a 2 cm. longitudinal incision made in the artery. About 12 cm. of clot was removed and a moderate rush of blood came from the proximal end of the artery. The holding sutures in the artery wall were approximated, a piece of sartorius muscle placed over them, and a second row of Lembert sutures inserted. Heparin was injected in the artery. The return of pulsation in the common femoral artery was only moderate, while in the superficial femoral it was practically absent. The patient died 26 hours after operation with increasing gangrene of the left leg.

It is believed that this patient either developed new emboli, or the previous ones were incompletely removed at operation.

CASE 10.—T. B., a man, aged 41 years, was ill for one week with a temperature of 104° F. and weakness. He awoke at 4 A.M. on May 1, 1935, with pain and numbness in the right hand and fingers. There was marked discoloration of the hand and absent pulse at the wrist with normal pulsation at the elbow. The patient was first taken to another hospital and then transferred to ours. The arm was placed in the pavaex machine with some very slight improvement, but embolectomy was decided upon and was done by one of us (R. D. McC.) at 11 P.M., nineteen hours after the accident.

*Operation.*—The bifurcation of the brachial artery was exposed under local anesthesia. Pulsation was visible down almost to the bifurcation, but none below. A longitudinal incision was made into the artery and a clot extending into both the

ulnar and radial branches was removed. The clot was not adherent, but it was thought at the time of operation that a piece may have broken off and gone into the radial artery. The ulnar remained clear. After irrigation of the main wound with salt solution, the arteriotomy wound was closed. Pulsation immediately came through after removal of the clamp and was felt plainly in the ulnar artery, but not in the radial. The color of the hand improved for a time but never became normal so that amputation in the upper third of the right forearm was performed one week later. The patient was improved when last seen three months after operation. A history of pain in the calves of the legs on walking as well as a positive finding of lead in the urine at that time are the only leads as to the causation of the embolus or thrombus.

Earlier operation might have saved this patient but that is uncertain. He was treated in the days before heparin and so did not have the advantage of that type of therapy.

*Results of Operation.*—The ideal result includes a return of the limb and of its pulse to normal. Tardy recovery of the pulse after successful embolectomy is not uncommon, as pointed out by Ridell (1935) and Griffiths (1938). Deitch (1936) removed an embolus in the left leg, but the pulse did not return. Schein (1935) stated that an ideal embolectomy should result in recovery of the pulse. If Schein's criterion for a successful embolectomy that there must be a return of peripheral pulsations below the site of obstruction is adopted, it would be hard to explain the results of arteriectomy or certain cases collected by Danzis (1933). In Danzis' series, 10 patients with embolic obstruction to the upper extremity, observed six months or more after embolectomy, had perfect functional results, but no peripheral pulsations present in the healed limb. Mosny and Dumont (1911) noted a late return of the pulse in their otherwise successful case.

Other after effects of operation persist in certain cases. Glen (1941) reported the case of a temporary vascular occlusion ending fatally in uremia. Persistence of ischemic neuritis after an otherwise successful arterial operation was described by Schein (1935) after arteriectomy for embolism of the brachial artery. One month postoperatively there was still evidence of hypalgesia and hypesthesia as well as of diminished position and vibration sense in the hand except in the distribution of the ulnar nerve which recovered first. In two of Griffiths' (1940) successful cases of embolectomy and in one case which became a failure—three in all—contractures developed, one of the hand and forearm, two of the calf and foot. In these cases the vein was not involved and Griffiths concluded: "Volkmann's contracture is due to arterial occlusion and to nothing else." DeTakats (1936) reported that he had under observation five patients who had survived leg embolism without gangrene and without embolectomy. Such extremities are pulseless and atrophic, the muscle contracted and fibrosed, and the skin scaly and mottled. Allen and MacLean (1935) reported success in a case of embolism of the right leg.

A few hours later, however, the left leg became occluded and neither papaverine nor pavaex was successful.

Reports of two illustrative cases follow, one an example of complete return of function and of pulse, the other an example of almost complete functional return with practically no restitution of the pulse.

CASE 11.—C. G., a woman, aged 76 years, with hypertension, arteriosclerosis, and auricular fibrillation had a sudden attack of pain, pallor, and coldness of the left leg. Pulsation was absent below the left inguinal ligament. Operation was performed several hours later, on April 26, 1942, with a diagnosis of embolism of the left femoral artery.

*Operation* (H. N. H.).—The operation was performed under local anesthesia. First the patient was given a paravertebral injection on the left side. The resultant temperature rise was very slight, if perceptible at all. The paravertebral injection consisted of 10 c.c. of 2 per cent novocain into each of the spaces opposite the transverse processes of the first four lumbar vertebrae on the left side by the method advised by Leriche and by Ochsner. The patient was then placed on her back, and with local anesthesia, an oblique incision just below the inguinal crease was made, exposing the left femoral artery. This vessel did not pulsate at all below Poupart's ligament but above Poupart's ligament a definite pulsation was palpable. This indicated that the obstruction was probably just above and that a positive Nordentoft's sign was present. A vertical incision 1 cm. long was made in the artery, revealing it to be in fairly good condition, as far as the wall was concerned, although there was some arteriosclerosis. There was a very slight flow of blood from the distal portion of the artery but no pulsation. No blood came from the proximal end of the artery. Inserting a catheter and later a uterine probe upward, we finally dislodged a hard embolus about 1.5 cm. long and 8 mm. in diameter, which appeared to be an organized clot, probably from the heart. (See Fig. 5.) This was followed by an extensive pulsatile flow of blood, which went several feet across the table.

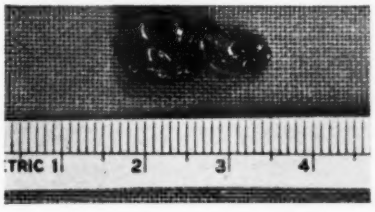


Fig. 5.—Embolus from femoral artery of C. G., Case 11, April 26, 1942.

At the same time, the distal portion of the artery showed a more prompt flow of blood. The incision in the artery was then closed with continuous fine silk in two layers. Immediately, following the closure, 2 c.c. of heparin were injected into the artery just above the suture line. The wound was then closed superficially, using silk throughout in the usual manner. Immediately after the operation, the popliteal and tibialis anterior pulsations were as marked as on the normal side and the temperature of the leg had markedly improved.

Immediately after operation the foot became warm and all pulses returned. On the eighth postoperative day the patient was able to get out of bed and walked without a limp. She was entirely well as far as the left leg was concerned when last seen on July 31, 1943, fifteen months after operation.

CASE 12.—G. G., a colored man, aged 39 years, had an old mitral stenosis and auricular fibrillation. He was admitted to the hospital on Nov. 16, 1940, with de-

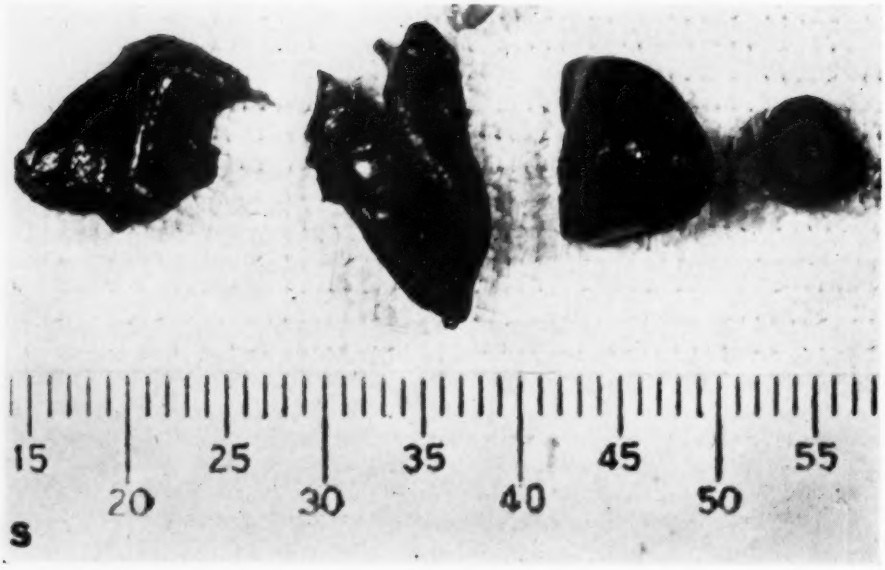


Fig. 6.——Emboli from femoral artery of G. G., Case 12.

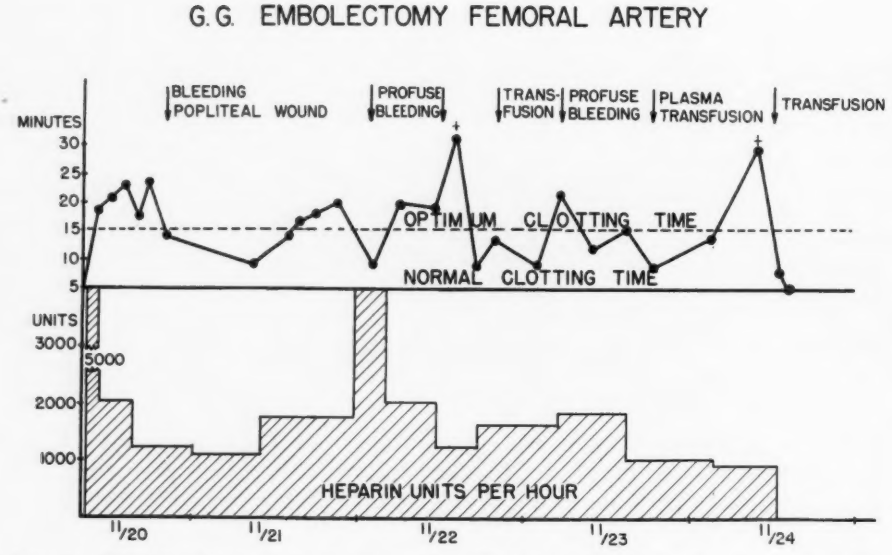


Fig. 7.—Heparin chart of G. G., Case 12. (We are indebted to Dr. C. R. Lam for preparation of this chart.)

compensation and four days later developed a sudden pain in the left leg and foot, with pallor and coldness. A diagnosis of popliteal embolus was made because of the presence of a femoral pulse. It was later found that the pulse was not present except as transmitted down from the iliac (positive Nordentoft's sign). A left paravertebral sympathetic novocain injection was done without much relief so operation was performed four hours after the accident.

*Operation* (H. N. H.).—A vertical incision over the popliteal fossa exposed the popliteal artery which was opened. No clot was found but no blood flow was present. A catheter introduced upward to its full length encountered no obstruction, so the arteriotomy and superficial wounds were closed and a vertical incision was made over the femoral artery. This was opened longitudinally and no blood flow was encountered. A catheter was passed upward 6 cm. and met an obstruction. The catheter was removed quickly with a piston action and on the second attempt the

Fig. 8.—Patient G. G. several weeks after embolectomy, standing on left, operated leg. There is slight swelling of the left ankle visible in the photograph.

clots (Fig. 6) came out after the catheter with a big rush of blood and landed 18 inches away from the wound. The catheter now passed freely and the arteriotomy wound was closed with two rows of continuous fine silk.

At the end of the operation there was only a slight relative coldness of the left foot instead of 8° F. difference as before. Arterial pulsation could be felt down as far as the adductor tubercle below Hunter's canal but not further. Heparin was started during the operation (Fig. 7). The left foot improved and although the

pulsations below the knee never returned and the patient walked with a slight limp, he had a useful leg as shown in Figs. 8 and 9. Because of some causalgia-like pain in the left foot, two left lumbar novocain blocks were done with an interval of three days one month after operation with improvement. There was a definite (2° F.) but slight relative increase in temperature of the left foot each time. The patient was improved until July 7, 1941, when he died from a pulmonary embolus.

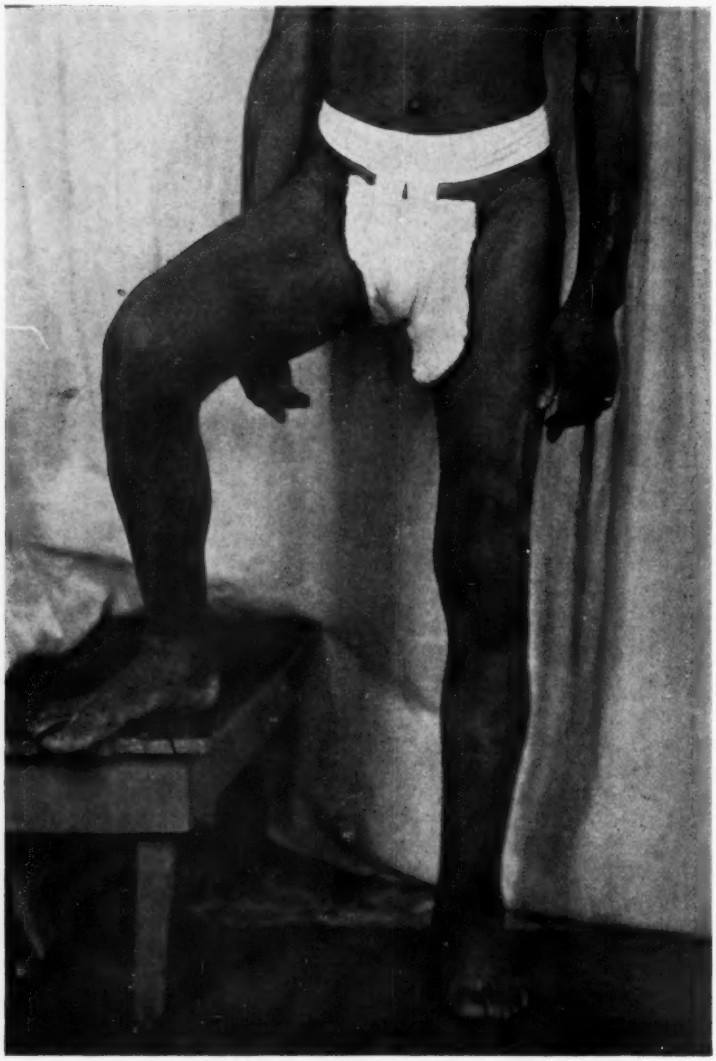

Fig. 9.—Front view of same.

## SUMMARY AND CONCLUSIONS

1. A series of 690 peripheral arterial embolectomies reported in the literature is reviewed. This study re-emphasizes the need for prompt diagnosis and early treatment.

2. Early peripheral arterial embolectomy (preferably under twelve hours from the time of the accident) performed under local anesthesia

and supplemented by lumbar sympathetic novocain block, papaverine, and heparin seems to be the best treatment for lower extremity embolism. Conservative management is advised in most instances of arm embolism. Arteriectomy or amputation should be reserved for difficult or late cases. Heparin acts rather to make more early embolectomies successful, than to prolong greatly the time after which operation can be performed.

3. Ten cases are presented of embolectomy or thrombectomy done at the Henry Ford Hospital as well as one additional instance of attempted embolectomy. Two of these represent undoubted thrombectomies and the patients should not have been operated upon (Cases 1 and 2). Of the remaining 8 cases, 1 was a complete success (Case 11), 1 a complete success but the patient died of cerebral embolism over a year later (Case 5); 1 had a recovery of the limb but not of the pulse and died of pulmonary embolism eight months after operation (Case 12). Two patients with embolectomy as well as the one with attempted embolectomy had to have subsequent amputation and recovered (Cases 7, 8, and 9), while 3 patients died (Cases 4, 6, and 9). The results in this series are not as good as some of those reported in the literature but are representative of the difficulties encountered in this condition.

4. Twenty-one successful aortic embolectomies reported in the literature are reviewed.

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# Review of Recent Meetings

## MEETING OF THE AMERICAN ASSOCIATION OF GENITO-URINARY SURGEONS AT STOCKBRIDGE, MASS., JUNE 10-12, 1943

C. D. Creevy, M.D., Minneapolis, Minn.

The June 10 session included the following:

**W. N. Wishard, Jr.,** of Indianapolis, discussed the techniques and difficulties of removal of stones from the lower third of the ureter. The latter included the breaking of a wire of a Johnson stone extractor.

**Vincent Balkus** of Philadelphia (by invitation) described a new stone extractor consisting of an ureteral catheter through the butt end of which a fine stainless steel wire is threaded, emerging from one eye and passing through the other back down the lumen of the catheter. The catheter is passed above the stone, then looped in the ureter by traction on the wire. The catheter, its end kept looped, is then withdrawn (with the stone, if Providence smiles). The instrument was successful at the first trial in ten of thirteen cases.

**D. M. Davis** of Philadelphia advocated the treatment of stricture of the ureteropelvic juncture and upper ureter by incising the stricture longitudinally, making a nephrostomy, and threading a rubber catheter down the ureter. No sutures are used in the ureter, Nature being left to her own devices in reconstructing the ureter during the three weeks while the catheter is in place. Keyes had done such an operation and had found the kidney in good condition many years later. It seems to the reviewer preferable, where possible, to use the Schwyzer-Foley Y plasty which actually widens the narrow area with tissue from the renal pelvis, and thus depends less upon chance for its success. When McIndoe depended upon a catheter to prevent stricture formation in a tubular Thiersch graft used to form an urethra in hypospadias, he found it necessary to leave the catheter in place for six months.

**H. G. Bugbee,** New York, discussed a patient who had hypertension and uremia due to a stone in the ureter of a solitary kidney. In performing nephrostomy, Bugbee found that compression of or traction upon the renal pedicle caused paroxysmal rises in the blood pressure. The blood pressure returned to normal after drainage of the kidney and subsequent removal of the stone. This observation is evidence of a neurogenic factor in hypertension.

**Leon Herman** of Philadelphia reported a large adrenal cortical carcinoma in an adult with normal secondary sex characters. Another patient had a huge perineural fibroma. Both displaced the kidney.

**N. P. Rathbun*** and **H. L. Wehrbein** (by invitation) of Brooklyn discussed six cases of lymphosarcoma of the bladder, five from the literature, and one of their own. They believe that such tumors develop in lymph follicles formed during chronic pyogenic infections.

Received for publication, Aug. 12, 1943.

*President of the American Association of Genitourinary Surgeons.

**Frank C. Hamm,** Major, Army U. S., Cambridge, Ohio, discussed the organization, construction, and operation of an Army General Hospital in a very instructive manner. The chief urological problem in such hospitals is, of course, gonorrhea. It was Hamm's opinion that sulfathiazole is as effective as any other sulfonamide and that, if a dosage of 6 Gm. daily does not yield a cure in three days, it is best abandoned. Eighty per cent of sulfonamide-resistant cases have responded to a combination of sulfathiazole and a therapeutic fever of 105° in the cabinet for five hours.

After gonorrhea, stones and congenital anomalies are the commonest urogenital disorders in troops not in combat.

**Clyde Deming,** New Haven, reviewed his experience with lesions of the urinary tract which disqualified men under selective service. Stones were most frequent, but hydronephrosis, pyelonephritis, tuberculosis, and post-traumatic disorders were not rare.

**E. G. Crabtree** of Boston described an instance of a teratoma primary in the epididymis. This tumor is thought to arise in cell rests from the genital ridge, included in the epididymis during development. Crabtree found ninety-two cases in the literature.

The meeting on June 11 included the following:

**J. C. McClelland** of Toronto, and **J. K. Ormond** of Detroit both discussed fatal cases of anuria from sulfathiazole in which the renal tubules exhibited at necropsy, not crystals, but degenerative changes and vascular thromboses thought to be toxic in origin.

**R. C. Graves,** Boston, castrated a patient with an undifferentiated carcinoma of the prostate with metastases after subjecting the gland and the involved supraclavicular lymph nodes to biopsy. Stilbestrol was also given. Seven months later the patient felt well and had gained twenty pounds, while the prostate was smaller and softer. Biopsy of the involved nodes showed histologic evidence of regression. This is interesting because it has been suggested that, if the serum phosphatase is normal (as in this case) or if the tumor is undifferentiated, therapy with castration or estrogens is likely to fail.

In the ensuing discussion, **Herman** also reported success from castration in an anaplastic prostatic cancer. **Nesbit** has had 60 per cent of "delayed failures" (recurrences) after castration, and believes that, since the duration of its good effects is limited, it should not be used until the occurrence of pain demands it.

**Hugh H. Young** of Baltimore, and **G. R. Livermore** of Memphis each reported surgical cures of nonfilarial elephantiasis of the scrotum from excision of enormous amounts of tissue. Dr. Young's presentation was accompanied by an excellent motion picture, in kodachrome, of the operation.

**P. B. Hughes** (Philadelphia) described a method of studying peristalsis in the intact, undisturbed ureter, an unusual achievement. Diodrast is given intravenously with the patient in the Trendelenburg position, and a segment of the ureter is photographed periodically through a slit, on adjoining segments of film by means of the urokymograph. The frequency and amplitude of the peristaltic waves can be measured. The method, if consistently successful, seems to offer great possibilities in the study of the effects of drugs and diseases upon ureteral peristalsis.

**E. L. Keyes,** New York, reported an unusual case in which cutaneous ureterostomy was performed in a physician with tuberculosis in a solitary kidney. He led

an active life thereafter for twenty-two years before dying, after a rapid decline, of renal tuberculosis. Necropsy disclosed extensive renal and peritoneal tuberculosis. This is a potent testimony to the usefulness of cutaneous ureterostomy.

**Meredith Campbell** of New York reviewed a series of 152 cases of stenosis of the external urinary meatus in children. This apparently trivial lesion has produced an appalling array of disturbances in the urinary tract, chiefly in the way of residual urine, hydronephrosis, and infection.

**C. D. Creevy,** Minneapolis, compared the operative blood loss in a series of fifty-one consecutive cases of transurethral resection of more than 30 Gm. of prostatic tissue with that of a similar series in which a mixture of saline, pitressin, and adrenalin had been injected into the gland just before and during operation. Since the loss of blood was reduced by 35 per cent, the method appears to offer some promise as a means of diminishing the risk and increasing the completeness of the operation.

The June 12 session included the following:

**A. I. Dodson,** Richmond, Va., discussed his experience with the Deming nephropexy, in which the peritoneum and perirenal fat are sutured beneath the lower pole of the kidney to the lumbar muscles. (Reviewer not present.)

**G. F. McKim** and **Parke G. Smith,** Cincinnati, reported on a patient who lived for twelve years in comfort with one-fourth of one kidney. (Reviewer not present.)

**C. R. O'Crowley** with **H. S. Martland** (by invitation) of Newark, N. J., presented evidence in the form of kidneys secured at autopsy, that small islands of normal adrenal tissue are not infrequently found beneath the renal capsule, and speculated on their relationship to the so-called Grawitz tumors of the kidney (hypernephroma, renal carcinoma).

**W. F. Braasch** of Rochester, Minn., reviewed fifty cases with unmistakable evidence of past trauma to one kidney. The blood pressure was normal in thirty-eight of forty-five cases in which it was recorded. Braasch doubts whether post-traumatic lesions produce hypertension.

**J. W. Lord** (by invitation) and **A. R. Stevens,** New York, described their experience with the implantation of the dog's ureters into the colon with the aid of tubes of the alloy called vitallium. They were inserted into the ureters so as to protrude into the colon in order to prevent temporary occlusion of the ureters during the postoperative reaction. While the tubes were ordinarily expelled within thirty days, the incidence of plugging by urinary salts was too high to permit use of the method in man.

**Charles C. Higgins*** of Cleveland has transplanted the ureters into the sigmoid in eighteen infants, between 2 and 11 months of age, for exstrophy of the bladder, with two deaths. He pointed out that 50 per cent of patients with exstrophy will die before the age of 10 years, and 65 to 70 per cent before 20 years if the condition is not corrected. He presented his reasons for early operation as follows: (1) Infants tolerate the operation well; (2) the intestinal organisms are less virulent than they will be later; and (3) there is less danger of subsequent ureteral dilatation and renal infection. He concluded that the results have thus far more than justified early operation. He uses a two-stage "Coffey No. 1" technique, splitting the end of the ureter, using a Mayo fixation suture, and places a single row

*Secretary of the American Association of Genitourinary Surgeons.

of fine stitches in the bowel. There were two eviscerations on the sixth day when catgut was used, but none have yet occurred since the adoption of stainless steel wire for closure.

**W. E. Lower** of Cleveland discussed the late results of uretero-enterostomy for nonmalignant disorders. Patients are prepared for operation with daily catharsis, a low residue diet, and sulfasuxidine. The cathartic is replaced by paregoric on the day before operation. Both ureters are transplanted simultaneously in the adult, but a two-stage procedure is preferred in infants. Six of eighty patients are alive twenty years or longer after operation, and five of these are in good health. Excretory urography showed that some degree of hydronephrosis was not uncommon.

In the discussion, **Young** reported that he had done plastic repairs in four cases of exstrophy, but that the failures had outnumbered the successes.

**G. G. Smith** (Boston) studied the late results in fifty malignant tumors of the testicle (teratomas, embryonal carcinomas, chorioepitheliomas) treated by orchidectomy and irradiation and followed as long as fifteen years. Nineteen were living one to fourteen years after treatment, fourteen of them more than four years. Results were poor when metastases were recognizable at the outset.

**H. Q. Woodard** (by invitation) and **B. S. Barringer** (New York) have accumulated a considerable series of cases of carcinoma of the prostate in which the acid and alkaline phosphatases in the blood serum have been measured. Twenty-six per cent had normal values in the presence of metastases, a fact which considerably reduces the value of the phosphatase determination as a diagnostic measure.

# Book Reviews

**Gynecology Including Female Urology.** By Lawrence L. Wharton. 1943. W. B. Saunders Company.

The author is a member of the department of gynecology (which includes female urology) of the Johns Hopkins Hospital and Medical School. He has put into this text for students the practice of that department in both fields. The text is profusely illustrated with, for the most part, previously published cuts.

This book has distinct possibilities as a teaching text and the author has organized the material with that in mind. He attempts to give the student a variety of interpretations where disagreement is recognized. Little of personal opinion or dogma is included. The references are almost exclusively to the English literature.

Some details will undoubtedly be improved in subsequent editions. Some of the embryology requires reconsideration. There are generalizations, particularly in dealing with uterine bleeding and malignant disease, which will not be generally accepted. The classification of uterine tumors is incomplete.

As a student text, however, this text is better than the average of those recently published.

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**Blood Groups and Transfusion.** By Alexander S. Wiener, M.D., Serologist and Bacteriologist in the office of the chief medical examiner of New York City. Ed. 3. Pp. 438. Springfield, Ill., and Baltimore, Md., 1943, Charles C Thomas, Publisher. Cloth. $7.50.

This book has kept abreast of the rapid advances made in the field since the first edition appeared in 1935. As the title indicates, it is still primarily concerned with the various theoretical aspects of the blood groups while only 160 pages are devoted to the routine problems of blood transfusion.

In the field of blood groups, the author writes with authority. The chapters on the heredity of the blood groups are complete and detailed. Dr. Wiener deserves the credit, along with Dr. Landsteiner, of the discovery of the Rh factor and his chapter on this subject is clear and restrained. There are exhaustive sections devoted to group-specific substances in organs, to anthropologic investigations, and to groups in animal blood. Two valuable chapters cover the medicolegal applications of blood grouping. There is a brief history on blood transfusion.

The problems of blood transfusion are approached from the viewpoint of the laboratory worker. The material on blood grouping and cross-matching is exhaustive. The selection of the donor has been treated at length but he receives scant attention as a patient. There is no reference to the reactions in donors which are occasionally a source of anxiety to the transfusionist. The author has wisely decided against an attempt to describe many techniques for transfusion but his selections are, in some ways, unfortunate. Much space has been devoted to the difficult, and

now rarely used, Kimpton-Brown paraffin tube method and to the various syringe apparatus while there is no mention of the "closed system" which is steadily gaining in popularity. A semiclosed method, however, is recommended in the chapter on preserved blood.

The material on transfusion reactions has been greatly expanded in this edition and the subject is, in the main, adequately covered. The author accords only a few lines to the subject of overloading of the circulation. It probably deserves more recognition. The transfusionist should certainly be impressed with the fact that prompt diagnosis and the application of tourniquets are necessary to save the lives of some recipients.

A new chapter has been introduced in this edition on stored blood, plasma, and serum. The author is lukewarm in his attitude toward stored blood. The advantages are mentioned but not emphasized. Description of the various techniques of preservation is scant. The problems of the administration of a blood bank are not discussed. The preparation and use of plasma and serum have been treated in somewhat more detail.

In spite of these imperfections, the book stands as the best reference work on blood groups in English.

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**Diseases of the Nose, Throat and Ear: Medical and Surgical.** By William Lincoln Ballenger, M.D., F.A.C.S., late professor and head of the Department of Otology, Rhinology and Laryngology, University of Illinois College of Medicine, and Howard Charles Ballenger, M.D., F.A.C.S., associate professor of Otolaryngology, Northwestern University School of Medicine. Ed. 8, thoroughly revised. Pp. 975, with 604 engravings and 27 plates. Philadelphia, 1943, Lea & Febiger. $12.00.

This large but compact volume has five sections. The titles are: The Nose and Accessory Sinuses, the Pharynx and Fauces, Diseases of the Larynx, the Ear, and Bronchoscopy.

This eighth edition seems to be thoroughly up to date in its content. Several specialists have contributed to the text in addition to the Ballengers. J. D. Kelly describes his technique of arytenoidectomy for bilateral paralysis of the recurrent laryngeal nerve. A description of B. T. King's operation for this condition is also included. Revised chapters on Peroral Enoscopy are provided by Gabriel Tucker and C. L. Jackson. Alfred Lewy contributes the chapters on Physiology and Functional Tests of the Labyrinth and Inflammatory Diseases of the Labyrinth.

Included in this eighth edition is a description of Lempert's end-aural approach to the mastoid and his fenestration for otosclerosis.

The text is easy to read. Each subject in its section is discussed in orderly fashion with paragraph titles such as etiology, symptoms, pathology, and treatment in large black type, making reference easy. Illustrations are numerous. Important bibliographic references are with few exceptions placed as footnotes.

In addition to the excellence of its content and arrangement, this treatise is noteworthy in that it is the most complete text in otolaryngology written by Americans. Also, it is the oldest treatise in the English language which has gone through eight editions, the last edition of which is up to date.

Otolaryngologists, graduate students in otolaryngology, and resident interns in the specialty should use this book. The physician in general practice will find it a most useful source for reference.

**Transurethral Prostatectomy.** By Reed M. Nesbit, University of Michigan. Pp. 192, with 94 drawings by Wm. P. Didusch. Springfield, Ill., 1943. Charles C Thomas, Publisher.

This book, written by one of the leading authorities in the field, should be read by everyone who does, or proposes to do, transurethral operations upon the prostate gland. Beginning with a chapter on the blood supply of the prostate by R. H. Flocks, who explains much that happens during and after such operations, it describes Nesbit's method of removing the obstructing portion of the prostate gland with an instrument of his own design. The descriptions are lucid and, coupled with the excellent drawings of Didusch, make the technique of the operation clear to the reader. There are detailed and helpful discussions of such pertinent topics as preoperative management, selection of an anesthetic, postoperative care, complications, and prostatic cancer, including comments on recent developments in this field. The history of the transurethral operation is well presented, and there is an excellent and extensive bibliography.

It might be well to explain that "transurethral prostatectomy" refers to a transurethral resection which seeks to remove as much of the hypertrophied prostate as possible, leaving behind but little more than the surgical capsule of the gland. It is a far cry from the original resection, which aimed at "cutting a channel" through the enlarged gland, and which was and is regularly followed by recurrent obstruction.

The reviewer, having seen the author at work, can testify that the book sticks to the facts in presenting what is, in the reviewer's opinion, the best method thus far devised for attacking the enlarged prostate gland transurethrally. It is not a method to be essayed by the novice.

## Books Received

The receipt of books is acknowledged in this section and this treatment must be regarded as sufficient acknowledgement of the courtesy of the sender. Selections will be made for more extensive review dictated by the interests of our readers and as space permits.

BLOOD GROUPS AND TRANSFUSIONS. By Alexander S. Wiener, A.B., M.D., Serologist and Bacteriologist in Office of Chief Medical Examiner of New York City; Head of Transfusion Division, Jewish Hospital of Brooklyn, N. Y. Cloth. Price $7.50. Pp. 438, with 69 illustrations, 106 tables. Springfield, Ill., 1943, Charles C Thomas, Publisher.

MANUAL OF INDUSTRIAL HYGIENE AND MEDICAL SERVICE IN WAR INDUSTRIES. By William M. Gafafer, D.Sc., issued under the Auspices of the Committee on Industrial Medicine of the Division of Medical Sciences of the National Research Council. Cloth. Pp. 508, with 19 illustrations. Philadelphia, 1943, W. B. Saunders Co.

TRANSURETHRAL PROSTATECTOMY. By Reed M. Nesbit, M.D., F.A.C.S., Associate Professor of Surgery, University of Michigan Medical School, Department of Surgery. Cloth. Price $7.50. Pp. 192, with 94 illustrations. Springfield, Ill., 1943, Charles C Thomas, Publisher.

PHYSIOLOGY IN AVIATION. By Chalmers L. Gemmill, B.S., M.D., Commander Medical Corps, U.S.N.R., Associate Professor in Physiology, Johns Hopkins University, School of Medicine, Baltimore, Md.; Instructor in Physiology, School of Medicine, Naval Air Station, Pensacola, Fla. Cloth. Price $2.00. Pp. 124, with 18 illustrations, 18 tables. Springfield, Ill., 1943, Charles C Thomas, Publisher.

THE SURGICAL CLINICS OF NORTH AMERICA—SYMPOSIUM ON TRAUMATIC SURGERY. By many contributors. Cloth. Pp. 638, with 153 illustrations. Philadelphia, 1943, W. B. Saunders Company.

OUTLINE OF ROENTGEN DIAGNOSIS. By Leo C. Rigler, B.S., M.B., M.D., Professor of Radiology, University of Minnesota, Minneapolis, Minn. Cloth. Price $6.50. Pp. 196, with 227 illustrations. Philadelphia, 1943, J. B. Lippincott Company.

CLINICAL SIGNIFICANCE OF THE BLOOD IN TUBERCULOSIS. By Culli Lind H. Muller, M.D., Pathologist and Director of Laboratory, New England Hospital for Women and Children, Boston, Mass. Cloth. Price $3.50. Pp. 516, 52 tables, 19 charts. New York, 1943, Commonwealth Fund.

OPERATIVE SURGERY, VOL. 1. By J. Shelton Horsley, M.D., LL.D., F.A.C.S., Attending Surgeon, St. Elizabeth's Hospital, Richmond, Va., and Isaac A. Bigger, M.D., Professor of Surgery, Medical College of Virginia; Surgeon-in-Chief, Medical College of Virginia Hospitals, Richmond, Va. Cloth. Pp. 674, with 705 illustrations. St. Louis, 1943, The C. V. Mosby Company.

OPERATIVE SURGERY, VOL. 2. By J. Shelton Horsley, M.D., LL.D., F.A.C.S., Attending Surgeon, St. Elizabeth's Hospital, Richmond, Va., and Isaac A. Bigger, M.D., Professor of Surgery, Medical College of Virginia, Surgeon-in-Chief, Medical College of Virginia Hospitals, Richmond, Va. Cloth. Pp. 1387, with 1259 illustrations. St. Louis, 1937, The C. V. Mosby Company.

A TEXTBOOK OF SURGERY. By John Homans, M.D., Clinical Professor of Surgery, Harvard Medical School, Boston, Mass. Cloth. Pp. 1272, with 530 illustrations. Springfield, Ill., 1940, Charles C Thomas, Publisher.

PAIN MECHANISMS. By W. K. Livingston, Lieutenant Commander, M.C., U.S.N.R., Associate Clinical Professor of Surgery, University of Oregon Medical School, Portland, Ore. Cloth. Price $3.75. Pp. 253, with 26 illustrations. New York, 1943, The Macmillan Company.

DIAGNOSIS OF UTERINE CANCER BY THE VAGINAL SMEAR. By George N. Papanicolaou, M.D., Ph.D., Department of Anatomy, Cornell University Medical College, and Herbert F. Traut, M.D., Department of Obstetrics and Gynecology, Cornell University Medical College and the New York Hospital. Cloth. Price $5.00. Pp. 46, with 11 plates. New York, 1943, Commonwealth Fund.

PICTORIAL HANDBOOK OF FRACTURE TREATMENT. By Edw. L. Compere, M.D., F.A.C.S., and Sam W. Banks, M.D. Cloth. Pp. 210, with 30 illustrations. Chicago, 1943, The Year Book Publishers, Inc.

MANUAL OF FRACTURES, TREATMENT BY EXTERNAL SKELETAL FIXATION. By C. M. Shaar, M.D., F.A.C.S., Captain, M.C., U.S.N., and Frank P. Kreuz, Jr., M.D., F.A.C.S., Lieutenant Commander, Medical Corps, U.S.N. Cloth. Pp. 300, with 148 illustrations. Philadelphia, 1943, W. B. Saunders Company.

SURGICAL CLINICS OF NORTH AMERICA—(BILIARY TRACT AND SURGICAL DIAGNOSIS). By many contributors. Cloth. Pp. 923, with 240 illustrations. Philadelphia, 1943, W. B. Saunders Company.

ROENTGENOGRAPHIC TECHNIQUE. By Darmon Artelle Rhinehart, A.M., M.D., F.A.C.R., Professor of Roentgenology, University of Arkansas, St. Vincent's Infirmary, Missouri Pacific Hospital, Arkansas Children's Hospital. Cloth. Price $5.50. Pp. 471, with 201 illustrations. Philadelphia, 1943, Lea & Febiger.

REHABILITATION OF THE WAR INJURED (A SYMPOSIUM). By William Brown Doherty, M.D., and Dagobert D. Runes, Ph.D. Cloth. Price $10.00. Pp. 684, with 160 illustrations. New York, 1943, Philosophical Library.

SURGICAL CLINICS OF NORTH AMERICA—ORTHOPEDIC SURGERY. By many contributors. Cloth. Pp. 1231, with 340 illustrations. Philadelphia, 1943, W. B. Saunders Company.

LINCOLN—DOUGLAS, THE WEATHER AS DESTINY. By William F. Petersen, M.D. Cloth. Price $3.00. Pp. 211, with 91 illustrations. Springfield, Ill., 1943, Charles C Thomas, Publisher.

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# SURGERY

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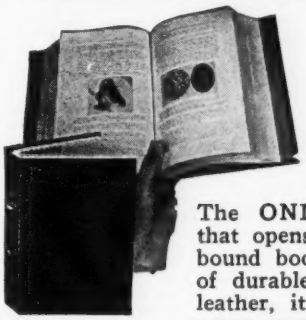

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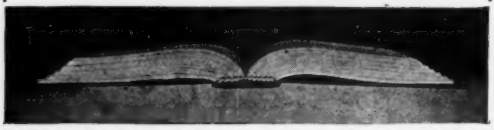

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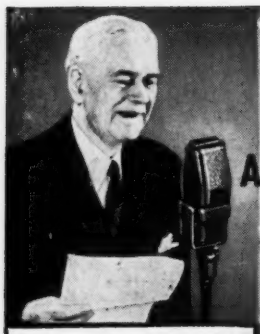

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